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GUEST EDITORIAL

The Study of Cycles

The study of cycles is of interest for two major reasons: (1) as a record of the past, and (2) as a possible means of prediction of subsequent events of a similar nature. It is to be understood that the meaning of the word 'cycle', as here used, applies to the recurrence of phenomena at more or less but not necessarily definite intervals. An outstanding example of such a recurrence of cosmic phenomena is to be found in the number of spots on the surface of the sun, which have been observed with remarkable continuity since the middle of the 18th century. The interval between occurrences of sunspot maxima has been far from constant and has varied from 7 to 17 years. The cause of the recurrence and of the variations in the intervals has not yet been found. The study of the sunspot curve, however, gave fair assurance that in an interval of about a decade since the last maximum in 1937, we might anticipate another major outburst. The cause may lie wholly within the sun or be due to a combination of events within the sun and cosmic phenomena exterior to the sun.

Another exhibit of cycles is to be found in near periodicities of weather changes which may persist for more or less indefinite periods such as is often shown in the recurrence of high or low pressure areas persisting across the United States at intervals of about a week especially noticeable during the winter season. Both of the illustrations here presented give us excellent examples of irregular recurrences for which definite periodicities cannot easily be assigned.

Exact periodicities are to be found in cosmic phenomena such as the diurnal rotation of the earth and the revolution of the earth and the planets about the sun. Since, in the realm of celestial mechanics, exact laws have been deduced from observations, it is possible in these instances to make predictions with a high degree of accuracy. It should be stressed, however, that the cycles themselves were long observed before the laws from which predictions could be made were defined. A law of nature, in itself, is to be interpreted not as a cause but rather as an exact statement of the way in which nature is observed to perform.

In dealing with a variety of topics in which the Foundation for the Study of Cycles is interested, we are not aware in most instances of the fundamental causes at work, but a persistent series of recurrences may give rise to hypotheses whereby the expectation of another recurrence may be timed. Until laws of performance can be mathematically stated, any prediction is an extrapolation of a curve, the meaning of which may be quite obscure and hence any prediction subject to uncertainty. The application of harmonic analysis may break down any complicated variation into a series of exact period that will reproduce the variations of past phenomena, but which may prove to be exceedingly disappointing in the prediction of a future event.

It is always the hope of divining some physical basis of past performances that is the stimulus for the continuation of the study of cycles. The longer the interval between recurrences, the more difficult is the discovery not only of the cause but even of the cycle itself. Temperature records in the temperate zones have been observed for such a long period of time that there is no difficulty in ascertaining the mean change in temperature between summer and winter. On the other hand, there may be large departures from the mean variations due to unusually cool summers or warm winters. Such departures can occur in an unpredictable feshion. If the span of a man's average lifetime were but a day rather than three or four decades many more generations would have to elapse before the seasonal variation in temperature would have been established. Recurrence of intervals of more than a decade are still somewhat difficult to establish because of the relatively short life span within which man can carry on his observations and pass on to succeeding generations knowledge that is pertinent to the discovery of the longer cycles.

It may be pointed out that where several recurrent factors synchronize at intervals, the period of recurrence in one class of phenomena may be obscured by a different period for a different class of phenomena. An illustration of this may be taken in the case of the synodic period Mars, the interval between conjunctions or oppositions, which is dependent upon both the period of revolution of the earth about the sun and that of Mars about the sun, both of which mean periods are exactly known. If the mean period of the earth's revolution about the sun (E) be taken as 365.25 days and that of Mars (M) as 686.98 days, then the synodic period of Mars (S) is given by the expression $\frac{1}{S}=\frac{1}{E}-\frac{1}{M}$ whence S=780 days, the interval between conjunctions or oppositions. It can be well appreciated that in the days of geocentric astronomy, a period of 780 days was discovered long before the component sidereal periods of E and M had been thought of.

We may use this analogy as applicable to an assumed case of a known periodicity of seven years in some biological phenomena. Let us suppose a solar cycle of eleven years is here involved, assuming an unknown period in the life cycle of some infectious micro-organism upon which a recurrent interval in biological phenomena depends. Utilizing the formula stated above, we can deduce the hypothetical life cycle supposed for an intermediary micro-organism, in which case the result from the calculations yield a period of 4.3 years for the micro-organism involved. Thus, a combination of an eleven-year solar cycle with a supplementary cycle of 4.3 years would give us the seven-year period for the components of which we made our quest. In the study of all cycle phenomena, cosmic, biological or economic, this illustration may be helpful in arriving at underlying factors.

While every encouragement should be given in the study of cycles, one cannot overemphasize the danger of extrapolation and resulting inferences as to future performance. Such inferences may well be a signal to guard us against unfortunate consequences in forecasting catastrophe or overoptimism.

New discoveries may, at any moment, introduce an important factor to interrupt a trend. A very recent discovery of 100 per cent or more increase in plant growth made possible through a timed alternation of light and darkness, for example, could in the end so profoundly alter horticulture as to mitigate if not remove the anxious worries of those who predict, on the basis of increasing population, a coming deficiency in the World's food supply.

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November 28, 1951

WAR CYCLES AND THE 6-YEAR CYCLE IN COTTON PRICES, 1731-1949

by
Edward R. Dewey

Summary

The writer discusses war cycles and the so-called six-year cycle in cotton prices in the United States.

Important wars are accompanied by major price increases which, in the past, have taken about 12 years to subside.

Cotton prices have been characterized by a so-called six-year cycle which seems to be a complex of four cycles—5.575-, 5.91-, 6.11-, and 5.45 years in length.

Trading in cotton on the basis of the 5.91-year cycle alone is shown to have been profitable 53 out of 71 times, with total net gains of 1109%; or 1407% if short positions had been avoided during wars.

The significance of this behavior is not evaluated, no opinion is expressed in regard to whether or not this cycle will continue, and no cause for the behavior is suggested.

An important question ever present in the minds of those whose business depends upon cotton is the probable price of the commodity. Upon a sound answer may depend the profitable operations of many investors and the success of business ventures. This report will set forth some of the factors bearing upon the future course of cotton prices as shown by the various patterns revealed in the history of cotton prices during the past 219 years. These patterns show not only the ups and downs correlated with wars but also fluctuations so regular that the liklihood of their continued recurrance in the future cannot be ignored safely.

With brief exceptions, cotton prices in the country are available by months from January 1731 to date, a span of 219 years. I have averaged the monthly prices to get annual averages in cents per pound for "crop years" running from August 1 to the following July 31 (Table 1). Averages have been computed from quotations at the following places:

August 1, 1731 to July 31, 1798, Philadelphia.
August 1, 1798 to December 1, 1940, New York.
January 1, 1941 to July 31, 1949, average of ten markets (note: data from January 1862 through December 1878 are in gold and comparable to rest of data, which are in currency.)

War and Post-War Behavior. It is obvious that wars cause major distortions, and the war of 1812, the War Between the States, World War I, and World War II all brought on sharp rises and falls in prices (Figure 1). The Spanish-American War showed no marked price changes. Data are not available for the Revolutionary War period, but the price of cotton in 1781-82 was but 1.1 cents above the 1775-76 price of 29.4 cents.

The War of 1812, the War Between the States, and World War I each had important effects upon the cotton market. At present we have the usual war and post-war advance. In the brief span of two years, the price rose from an average of 9.3 cents a pound in 1812 to 23.1 cents in 1814. By the end of 1817-18, three years after the war ended, the price reached 31.0 cents. (This overall rise occurred in six years, and the high post-war level was not approached again until Civil War days.) Twelve years after the War of 1812 ended (1826-27) the price of cotton declined to 10.2 cents, nearly its pre-war level.

From the beginning of the Civil War the price of cotton took only three years to skyrocket from a level of 12.3 cents in the crop year 1860-61 to a peak of 54.2 in 1863-64. In the following year, at the end of the war, the price was receding as rapidly as it rose and was down to 47.0 cents. Twelve years after the Civil War (1876-77) the price had come down to 10.9 cents. Although the price rose slightly during the Spanish-American War, there is no evidence that this rise was the effect of the war. In any event, the increase was not great enough to be reflected significantly in the price history of cotton. At the beginning of World War I, in the crop year 1913-14, the price was being quoted at 13.2 cents per pound. In four years the war carried the price to 29.6 cents per pound in 1917-18, and two years later (1919-20) the annual average price reached the peak of 38.3 cents. But 12 years after the war's end (1930-31) the average price had declined back to 10.4 cents.

Just before World War II, in the crop year 1938-39, the price of cotton was 9.0 cents. Six years later, at the end of the war (1944-45) the price was 21.9 cents and still rising. It reached an annual average level of 34.8 cents in 1946-47. The record shows that a dozen years after the end of a war, cotton prices have registered over-all declines from the peak year. These declines amounted to 20.8 cents (War of 1812), 43.3 cents (War Between the States), and 27.9 cents (World War I), respectively. Of course, no one knows whether or not World War II will be followed by similar declines. In trying to estimate cotton prices between now and 1957 (12 years after the end of the war), however, it would seem only reasonable for cotton growers, purchasers and investors to anticipate the possibility of a strong down-swing in cotton prices not unlike those that have developed in post-war periods of the past, except as such behavior might be prevented by governmental debasement of the currency.

The Six-Year Rhythm. Throughout its entire record of 219 years, the cotton market acts as if influenced by a rather regularly recurring up and down force, three years up and three years down,

six years from crest to crest. It has not always been entirely regular in its action, sometimes being shorter and sometimes longer than six years. Its effect has varied in importance, but the evidence shows the pattern, even though not always dominant. For the past fifty years, moreover, the wave has been of particular importance and of distinctive regularity (except for war distortions of 1940-41 through 1943-44 crop years), so that it should be taken into account definitely as a continuing possibility by anyone dealing with the future course of cotton prices.

Table I.

Average Annual Spot Price of Cotton per Pound
Crop Years 1731-2 to 1947-8

Crop Year	Cents per Pound	Crop Year	Cents per Pound	Crop Year	Cents per Pound	Crop Year	Cents per Pound	Crop Year	Cents per Pound
1731-32	12.7	1775-76	29.4	1818-19	24.67	1861-62	27.29	1904-05	9.09
-33	14.3	-77	-	-20	16.52	-63	46.98	-06	11.30
-34	13.6	-78	-	-21	14.88	-64	54.15	-07	11.24
-35	14.3	-79	-	1821-22	14.69	-65	46.98	-08	11.53
-36	13.8	-80	-	-23	11.18	-66	31.40	-09	10.23
-37	15.5	-81	-	-24	14.65	-67	22.94	-10	14.66
-38	15.1	1781-82	30.5	-25	17.92	-68	17.48	-11	14.87
-39	17.8	-83	38.2	-26	13.38	-69	20.92	1911-12	10.85
-40	17.8	-84	32.0	-27	10.20	-70	20.72	-13	12.29
-41	16.7	-85	31.4	-28	10.34	-71	15.16	-14	13.21
1741-42	13.4	-86	35.9	-29	9.89	1871-72	19.54	-15	-
-43	13.3	-87	40.2	-30	9.72	-73	17.64	-16	11.98
-44	14.0	-88	38.2	-31	10.14	-74	15.51	-17	19.28
-45	17.5	-89	30.5	1831-32	9.12	-75	13.87	-18	29.58
-46	21.5	-90	26.3	-33	11.40	-76	11.51	-19	31.01
-47	25.7	-91	21.9	-34	13.06	-77	10.94	-20	38.29
-48	25.8	1791-92	30.6	-35	16.29	-78	10.95	-21	17.89
-49	21.2	-93	34.6	-36	16.72	-79	10.82	1921-22	18.92
-50	24.0	-94	31.6	-37	14.36	-80	12.13	-23	26.24
-51	26.8	-95	32.2	-38	10.02	-81	11.36	-24	31.11
1751-52	27.9	-96	31.8	-39	13.22	1881-82	12.09	-25	24.74
-53	22.1	-97	28.5	-40	9.41	-83	10.81	-26	20.53
-54	22.4	-98	29.4	-41	9.58	-84	10.87	-27	15.15
-55	18.7	-99	29.8	1841-42	8.13	-85	10.74	-28	20.42
-56	19.7	-00	29.9	-43	7.24	-86	9.47	-29	19.73
-57	24.0	-01	28.7	-44	7.82	-87	9.91	-30	16.60
-58	19.2	1801-02	24.00	-45	5.88	-88	10.15	-31	10.38
-59	19.8	-03	18.30	-46	7.77	-89	10.44	1931-32	6.34
-60	18.5	-04	18.08	-47	10.89	-90	11.27	-33	7.37
-61	18.6	-05	22.00	-48	8.54	-91	9.48	-34	11.09
1761-62	23.4	-06	23.50	-49	7.24	1891-92	7.68	-35	12.44
-63	25.1	-07	22.08	-50	12.02	-93	8.45	-36	11.75
-64	29.2	-08	17.75	-51	12.57	-94	7.75	-37	12.93
-65	27.6	-09	15.00	1851-52	9.30	-95	6.38	-38	8.75
-66	26.3	-10	14.83	-53	10.98	-96	8.10	-39	8.99
-67	27.5	-11	13.58	-54	11.01	-97	7.71	-40	10.34
-68	23.4	1811-12	9.33	-55	10.31	-98	6.40	-41	11.1
-69	20.2	-13	13.00	-56	10.33	-99	6.00	1941-42	18.3
-70	17.1	-14	25.50	-57	13.18	-00	8.36	-43	20.2
-71	17.3	-15	23.08	-58	12.46	-01	9.38	-44	20.6
1771-72	16.1	-16	28.33	-59	12.12	1901-02	8.73	-45	21.9
-73	20.0	-17	27.06	-60	11.27	-03	9.96	-46	26.0
-74	19.1	1817-18	30.99	1860-61	12.27	1903-04	12.84	-47	34.8
1774-75	23.8							1947-48	34.6

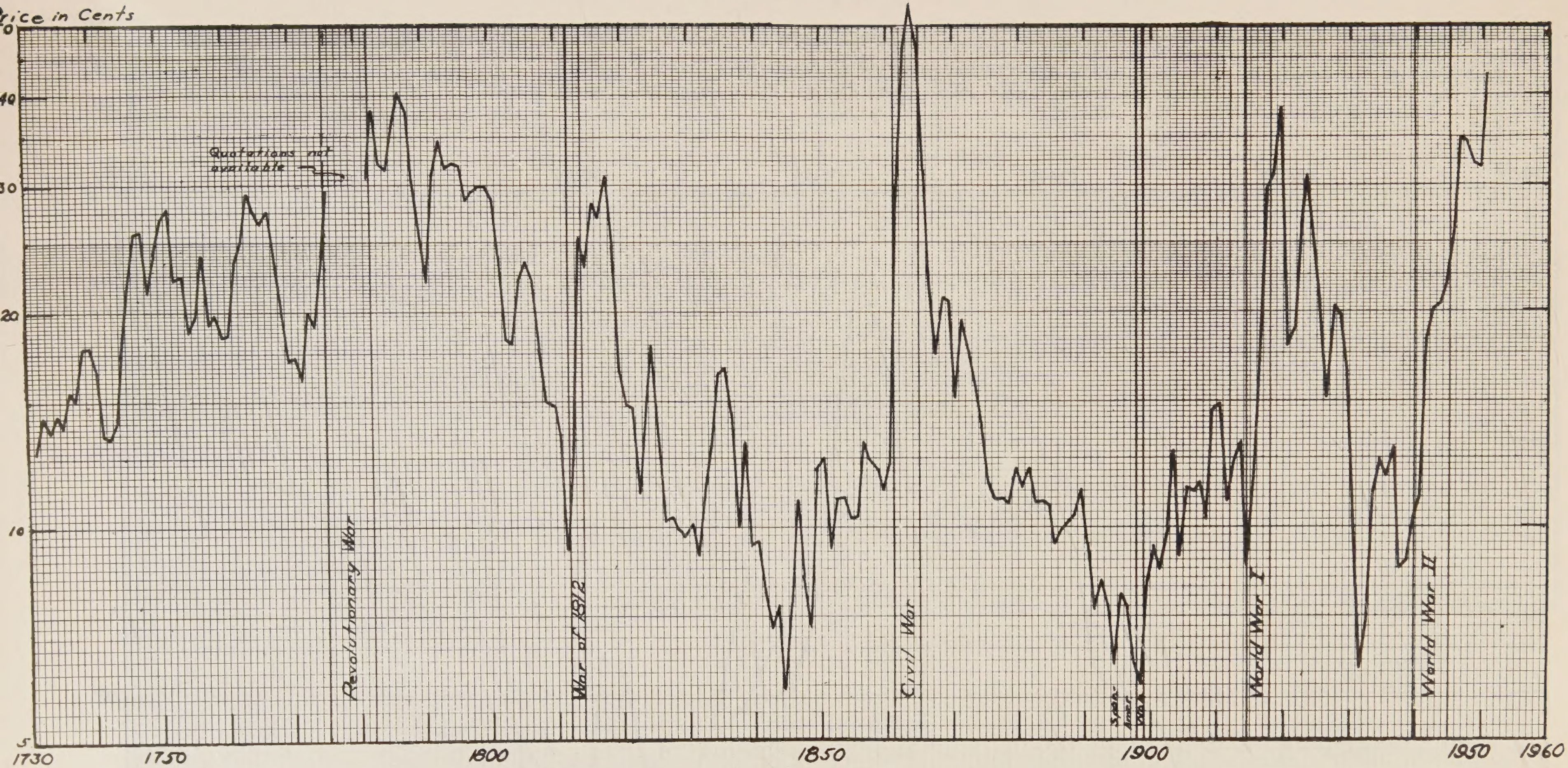


CHART 1
AVERAGE ANNUAL SPOT PRICE OF COTTON PER POUND
CROP YEARS 1731-2 TO 1950-1
(Ratio Scale)

Notes

Prices from August, 1731, through July, 1798, are quoted at Philadelphia.

Prices from August, 1798, through December, 1940, are quoted at New York.

Prices from January, 1941, through July, 1948, are the average for ten markets.

Data from January, 1862, through December, 1878, when the United States exchange was below par, are quoted in gold and are comparable with the rest of the data which are quoted in currency.

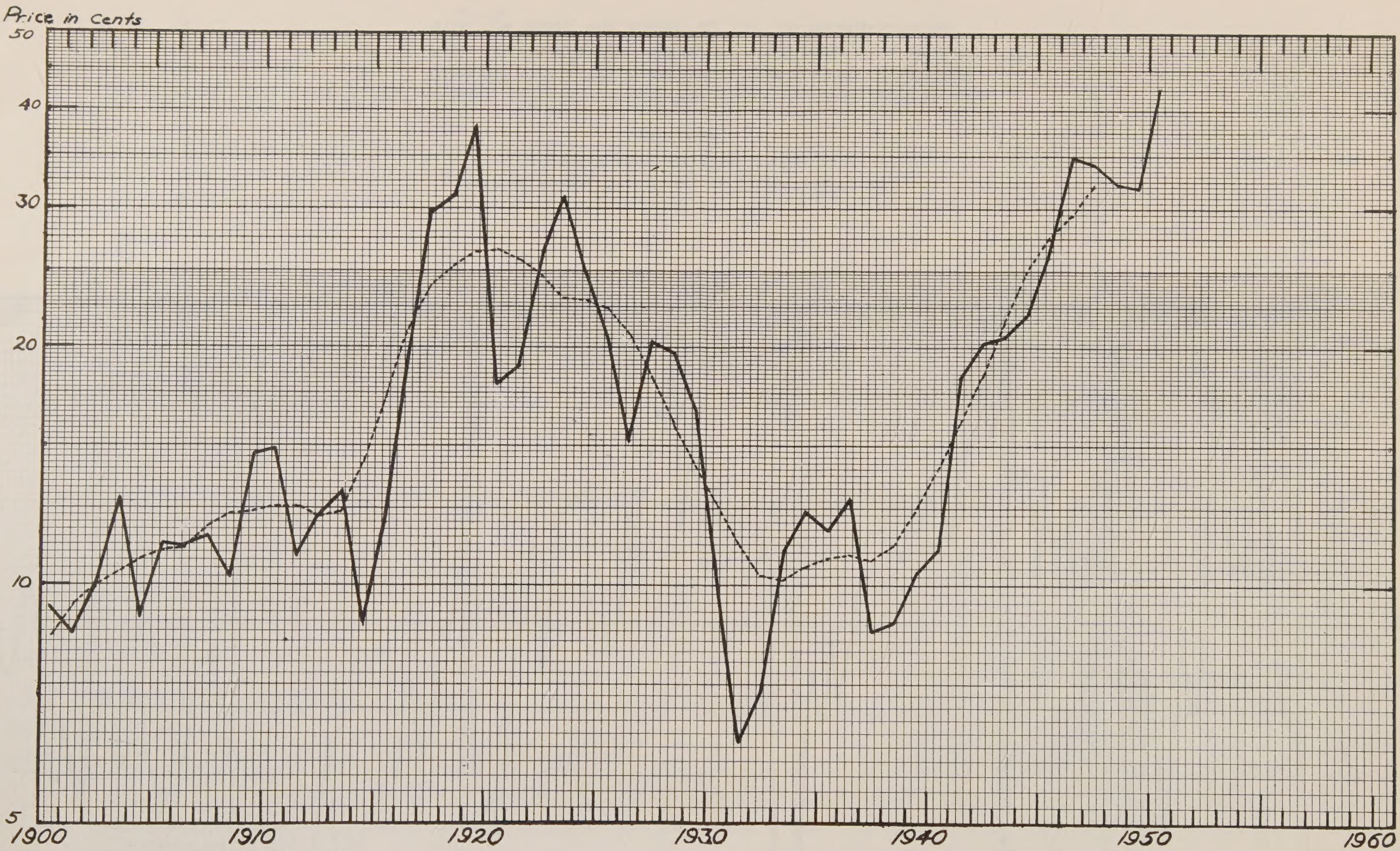


CHART 2

AVERAGE ANNUAL SPOT PRICE OF COTTON PER POUND, CROP YEARS 1900-1 TO 1950-1, TOGETHER WITH A 6-YEAR MOVING AVERAGE TREND OF THE DATA

(Ratio Scale)

——— Price of Cotton

----- 6-Year Moving Average Trend

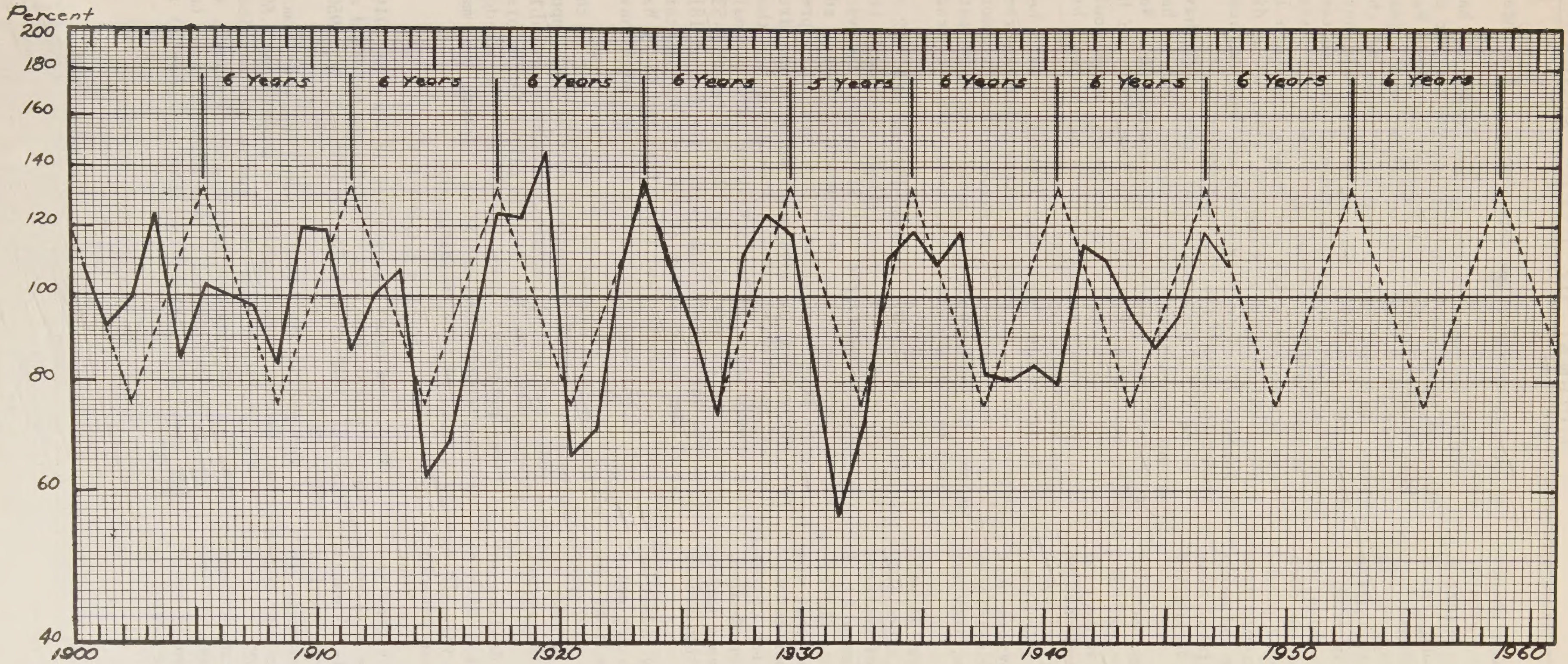


CHART 3

5.91-YEAR PATTERN IN THE AVERAGE ANNUAL SPOT PRICE OF COTTON PER POUND

(Ratio Scale)

——— Price of Cotton Expressed as a Percentage of the 6-Year Moving Average Trend

----- Diagrammatic Representation of the 5.91-Year Repetitive Pattern (Ten 6-year intervals and one 5-year interval and repeat)

A six-year cycle has been found in many phenomena, such as solar radiation, tree-ring growth, climate, and economic data. It is therefore a possibility that all are interrelated and that a six-year cycle is something very fundamental.

The six-year pattern in cotton prices seems to be a complex pattern composed of four overlapping repetitive forces of about six-years in length. One seems to be about 5.575 years long, which may be the cycle of 5.5-years identified in corn prices by Benner (1875). It might be added parenthetically that this pattern has been coming true faithfully since, so that anyone buying and selling corn from 1875 to 1948 on the basis of Benner's wave would have made a net gain during the period of 450% before brokerage.

A second pattern in the cotton prices seems to be about 5.91 years long. This one fits well as a submultiple of a longer wave of 17.75 years also appearing in our data. There are also indications of two other repeating patterns in this six-year group, one of about 6.11 years and the other about 6.45 years in length. It is obvious that when the rising phases coincide, they reinforce each other, but where they are opposite, they may partially neutralize each other.

Let us now examine the 5.91-year wave. It will be simpler if we use the cotton prices since 1900 when nearly all of the six-year group of patterns are rising and falling together (Figure 2). I have added a trend line that eliminates the effects of any six-year wave present, so that ups and downs of this line are due to other causes. Figure 3 shows the percentages by which cotton prices differ from this trend. On this graph also, an ideal 5.91-year cycle is indicated as a broken line, and the repetitive pattern of cotton prices is clearly evident.

The best test of the validity of any pulsation is the extent to which the predictions are reliable. We can predict the future pulsations now and wait to see. We can also test the 5.91-year cycle by applying it to the past as a year to year prediction and see how it fits the actual facts that did occur.

Thus, if we set your hypothetical dealing in cotton on the 5.91-year wave beginning with a purchase at average prices in the crop year 1731-32, our trader following the 5.91-year pattern would have sold and gone short in the crop year starting August 1734 and so on at 5.91-year intervals (ten six-year intervals and one five-year beginning with the first peak in 1734-35) until now. If our hypothetical trader had done so, his net gain (disregarding brokerage fees) from his original purchase date through the crop year ending July 31, 1947, would have been 1108%.

Fifty-three of the seventy-one transactions would have shown gains; eighteen, losses. I have omitted the two transactions that normally would have been made in the Revolutionary War period as we have no cotton price data available for these years.

But if our hypothetical cotton trader had had the good sense not to be short during the War of 1812, the War Between the States, and World War II, where the 5.91 pattern called for such a position, he would have eliminated three of the losses and his total gain as before would have been 1407%, not including additional good fortune if he had turned the three war losses into gains. These percentage gains and losses are shown in Table 2 and plotted in Figure 4, which shows diagramatically the fortunes of our hypothetical trader throughout the 218-year period.

Since 1902, our hypothetical trader would have had no losses (assuming, of course, that he had refrained from a short position during World War II), and his gains would have been 653%. If he had done no trading in the war years, which would be a truer measure of the effect of rhythms, his gains would have been 454%.

It is evident from this, I think, that a behavior pattern or group of patterns has occurred in the price series. It is evident also that more should be known about this pattern of these patterns by all who grow, buy, sell, use, or trade in cotton.

Future conditions. Between 1949-50 and 1952-53 crop years, the 5.91-year pattern is upward, but it should be emphasized that if post-war behavior of the past prevails, an enormous downward adjustment still lies ahead. If circumstances prevent our getting the adjustment normally due from 1946-47 to 1949-50, there is no assurance that the upward phase of the 5.91-year pattern could prevail in the period from 1949-50 to 1952-53. Observe, for example, that after the War of 1812 two of the upward phases of the 5.91-year pattern failed to dominate, and that after the Civil War three of the long positions indicated would have been overwhelmed.

The position assumed by a cotton trader in the crop year 1949-50, therefore, must be based upon a judicious mental combination of the probable effect of the post-war decline called for by historical precedent, plus, of course, a knowledge of other rhythms and artificial factors that may be introduced into the situation.

POSTSCRIPT

The above paper was written in June of 1949. Cotton prices from 1948 forward have unfolded as follows: 1948-49 - 32.2¢, 1949-50 - 31.8¢, 1950-51 - 42.7¢.

The profit that would have resulted from a short sale in 1946-47 would have amounted to 8.6%.

The profit or loss that would have resulted from the indicated purchase in 1949-50 cannot, of course, be determined at the present time, but for the first year of the move it amounted to 34.3%.

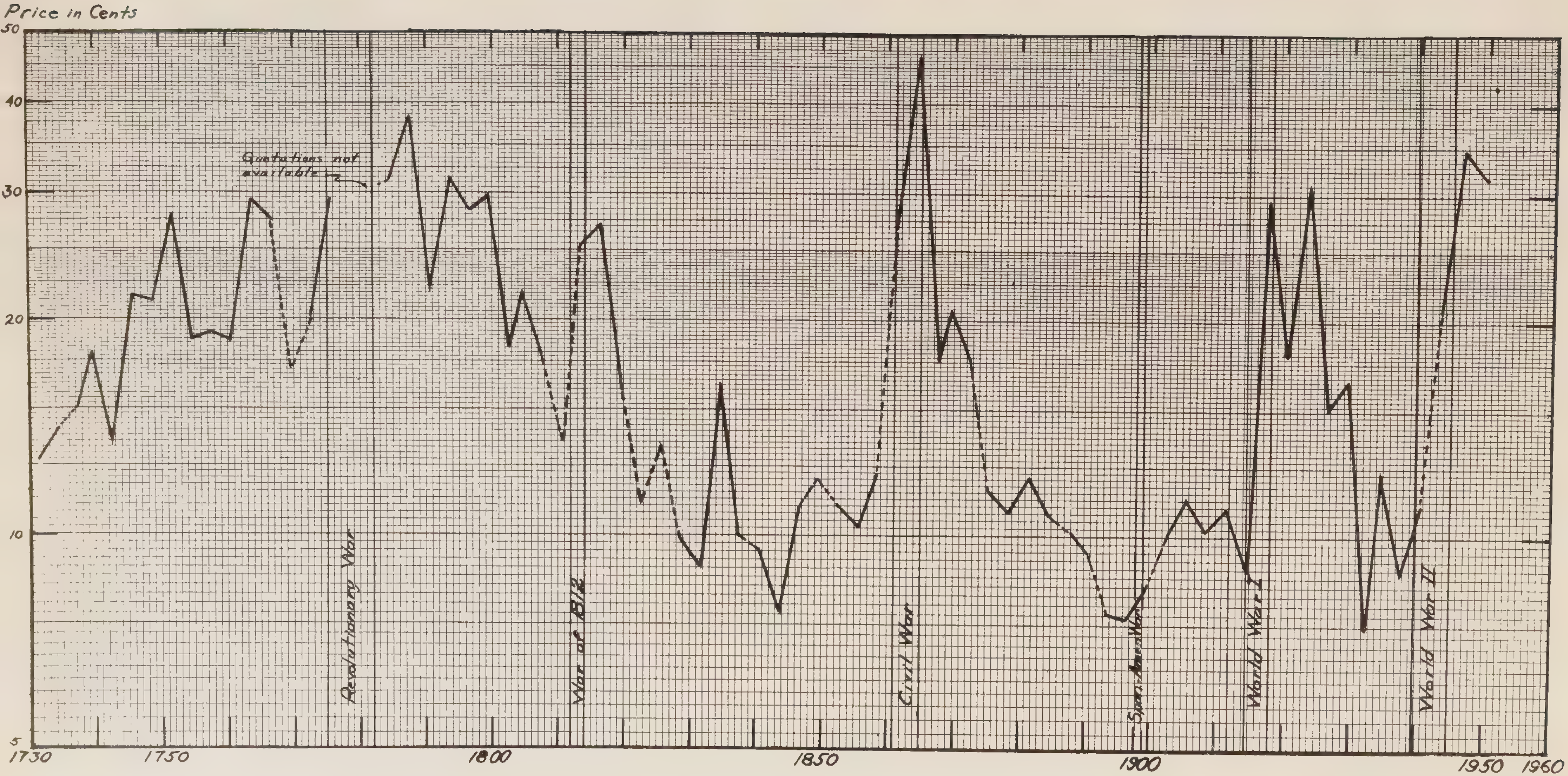


CHART 4

DIAGRAM SHOWING GAINS MADE AND LOSSES SUSTAINED BY BUYING AND SELLING COTTON ACCORDING TO THE REGULARLY RECURRING 5.91-YEAR PATTERN CROP YEARS 1731-2 TO 1950-1

(Ratio Scale)

——— Gain ------ Loss

Table 2.

Gains Made and Losses Sustained by Buying and Selling Cotton
According to the Regularly Reccuring 5.91-Year Pattern Crop Years 1731-2 to 1947-8

Buy Years	Sell Years	Buy-Sell Gain (Percent)	Short-Cover Gain (Percent)	Round Trip Net Gain (Percent)
1731-2				
	1734-5	13%		
1737			- 6%	7%
	1739	18		
1742			25	43
	1745	62		
1748			1	63
	1751	32		
1754			33	65
	1757	3		
1760			3	6
	1763	57		
1766			6	63
	1769	-38		
1772			-17	-55
	1775	47		
1778			a	a
	1781	a		
1784			- 3	44
	1787	22		
1790			43	65
	1793	44		
1796			10	54
	1799	5		
1802			39	44
	1804	20		
1807			19	39
	1810	-24		
1813			b	-24
	1816	6		
1819			39	45
	1822	-32		
1825			-20	-52
	1828	-26		
1831			8	-18
	1834	79		
1837			39	118

Buy Years	Sell Years	Buy-Sell Gain (Percent)	Short-Cover Gain (Percent)	Round Trip Net Gain (Percent)
	1840	- 4		
1843			19	15
	1846	40		
1849			-10	30
	1852	- 8		
1855			6	- 2
	1858	18		
1861			b	18
	1864	72		
1867			63	135
	1869	18		
1872			15	33
	1875	-35		
1878			6	-29
	1881	12		
1884			12	24
	1887	- 5		
1890			7	2
	1893	-18		
1896			1	-17
	1899	9		
1902			-19	-10
	1905	13		
1908			10	23
	1911	7		
1914			18	25
	1917	233		
1920			39	272
	1923	74		
1926			51	125
	1929	9		
1932			55	64
	1934	68		
1937			29	97
	1940	26		
1943-4			c	26
	1946-7	69		69
Total		886%	521%	1407%

a No quotations for Revolutionary War period.
b No short position assumed because of war
c No short position assumed because of war.

CAUSATION OF THE NINE OR TEN YEAR SALMON CYCLE

by

A. G. Huntsman

This cycle was discovered only a little over twenty years ago. An angler (Griswold 1929), in striving to account for the very poor salmon catch on the Grand Cascapedia River in Quebec in 1928, found a periodicity in such scarcity of about nine years for the previous two decades, not only in the records of the Grand Cascapedia Club, but also in those of the Club for the neighbouring Restigouche River and in the official statistics of the commercial or net catches of salmon for both New Brunswick and Quebec. Phelps and Belding (1931) subjected all the records of the Restigouche Salmon Club to refined statistical treatment to disclose any general relations to aid in an understanding of the salmon as related to its environment. They found mainly a 10-year cycle, which they were inclined to regard "as being due to some regular periodic influence upon the tidal or other oceanic conditions". As a result of the activities of the Royal Commission on Maritime Fisheries in 1928, an independent study was made of the official statistics for the net catches in the Maritime Provinces and in the Gaspe peninsula of Quebec (Huntsman 1931) "to discover the factors that determine fluctuations in the fisheries or that limit the abundance of the fish". A complex situation in periodicity was revealed, which included the cycle above mentioned as "a depression in abundance occurring on the average every 9.6 years of which the cause is unknown".

Low Water as the Cause

Six years later (Huntsman 1937) it was concluded from varied evidence that the basic factor for this periodic scarcity in salmon is low water in the rivers, and that the cycle is dependent upon periodicity in rainfall. This cycle, problematical and obscure as it has been from the start, not only is of outstanding importance for elucidation of a complex of salmon cycles, but also points the way to elucidation of biological cycles in general through its relation to variations in that most important and most variable factor for life—water. Owing to the spottiness of rainfall, the fluctuations in the availability of water for life are not only extremely complex, but also very difficult to determine.

Salmon are particularly suitable aquatic animals for revealing in their varying abundance the fluctuations in certain types of availability of water. In the first place, records that reflect changes in abundance are available over a long period, because (1) these fish are very abundant and large for a river fish, (2) they have been steadily in high demand, and (3) they are readily caught when migrating up rivers if not otherwise. They are good for showing effects from water fluctuations even in a region where water is generally ample, because they live, as it happens, in flowing water dependent upon rainfall at the stage in their life history when they are most crowded in getting a living and in surviving, that is, when limitations in space are most apt to affect their numbers. Not only do the salmon parr live in river rapids up to the stage of descent to the roomy ocean, but they occur characteristically in rivers that are particularly influenced by variable rainfall, that is, in those that are freshet swept and thus have clean beds of gravel, in which their eggs may have the necessary supply of oxygen from the water that percolates through.

Adequacy of Data

The catches or takes of salmon do not necessarily represent the comparative abundance of the fish. Also they are far from being free from human error. Fishing effort is an obvious variable that affects the catch, but it is most difficult to assess, since time spent - the usual criterion - may very inadequately represent the actual effort. Even if the effort were properly taken into account, such would not remove more than a small part of the variables that prevent the catch from accurately representing the abundance of the stock of fish. This is particularly true for angling, because both presence of the stock in the river and success in capturing them there are so much affected by variable weather. Main reliance must be placed, not upon particular figures, but rather upon the same pattern being repeated, not only in time and thus showing cycles, but also in space, that is from place to place, and with different personnel in obtaining and handling the data.

Evidence for the Cycle

The cycle is presumed to be a periodical fluctuation in abundance of salmon. Our knowledge of such fluctuation comes from fishermen's catches. To eliminate variability in the fishing effort, Phelps and Belding in handling data for the Restigouche River from anglers who lease the river, calculated the average number of salmon taken per rod per day in each year from 1879 to 1930. To give a smoother curve, they used a 3-year moving average. Since the local availability of the stock in a river during the season may vary greatly from year to year depending upon freshets from rainfall as demonstrated experimentally (Huntsman 1948), it might be questioned whether or not the take per rod per day by anglers properly represents the stock related to the river. This can be tested by the data of capture of the salmon in the sea by nets. Since salmon in the sea near the mouth of the Restigouche River have been shown by tagging experiments to migrate in nearly every

possible direction during the summer season for netting, there is clearly in any sea fishery a mixture of salmon related to various rivers. However, the salmon caught along both shores of Chaleur Bay in Restigouche County, N. B. and in Bonaventure County, Que., should reasonably well represent the Restigouche stock. It may be presumed that the fishing effort does not vary greatly from year to year, since net fishing is a regular business for livlihood. The annual landings of the salmon taken by nets in the sea (Table I) have been used for comparison with the take per rod per day in the river, and for the former as for the latter, a 3-year moving average has been plotted to give a smoother curve. In figure 1, the two can be compared for the period from 1879 to 1930, for which alone the angling results are available. The landings from nets cover the longer period from 1870 to 1950. It will be evident that there is general agreement as to there being a 9 to 10 year periodicity in the abundance of these salmon. In spite of the deficiencies in both methods, their agreement creates confidence in the result. The fluctuations are pronounced in the 70s, 10s, 20s, and 30s, but much less distinct and at lower levels in other decades.

The cycle was found to be more or less in evidence in salmon catches by nets throughout the Maritime provinces, creating further confidence that we are dealing with a reality and one of wide occurrence. This situation may be illustrated with data from three different districts. The first is related to the Saint John River, which as accessible to salmon arises in northern New Brunswick and reaches tide level at Fredericton, whence it flows to the Bay of Fundy through an 80-mile long estuary (mostly fresh). The salmon stock of this river seems to be quite discrete and is distributed in the bay in the outflow of the river along the coast to the southwest for fifty miles. It is represented for fishing in the bay of the landings for Charlotte and Saint John counties and for inland fishing in the estuary and the river by those for Kings, Queens, Sunbury, York, Carleton, and Victoria counties. The second district is related mainly to the Miramichi River, which discharges into the Gulf of St. Lawrence on the eastern coast of New Brunswick through a 30-

Table 1.
Hundredweights of salmon landed each year
from nets in Restigouche county, N. B. and Bonaventure county, Que.

	0	1	2	3	4	5	6	7	8	9
1870	7615	3932	4468	11854	14350	3512	3923	6527	10396	7957
1880	2968	2679	2539	3633	2938	4351	4828	4773	3173	3363
1890	2429	2638	2824	3622	4695	3239	5708	3589	3777	2742
1900	3087	4799	5925	3430	2786	3834	5026	5062	4964	5312
1910	5102	3782	4139	5636	6523	4759	8314	6430	5828	3678
1920	2447	3634	6351	8963	15431	15633	12071	10626	4811	5379
1930	7631	12942	7118	9460	9380	7054	6263	4596	5768	3854
1940	4368	6199	4600	4238	4108	4229	2661	2816	4284	3616
1950	4340									

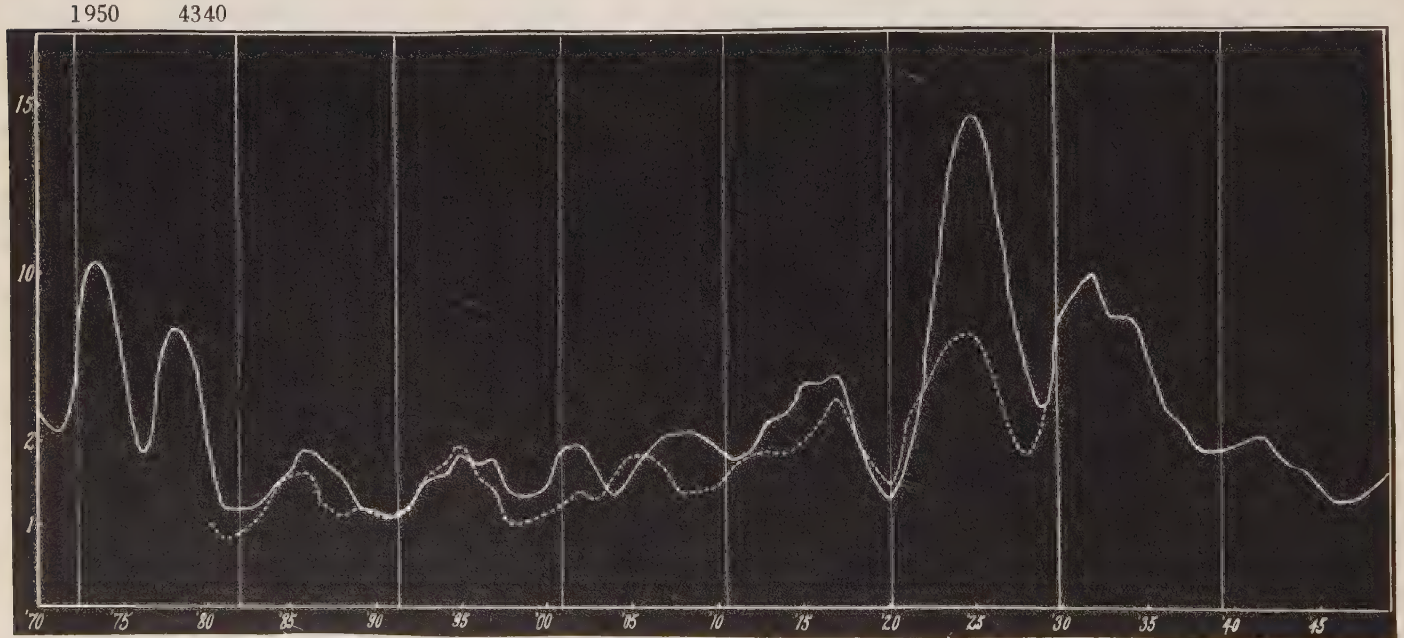


Fig. 1. Fluctuation in Restigouche salmon, as shown by annual changes in rate of angling (number taken per rod per day) in the river, and by annual changes in net catches in the adjacent sea (Restigouche and Bonaventure Counties), both curves smoothed by using three-year moving average.

mile long estuary. The fishery is by set nets in the estuary and by drift nets in the gulf off the mouth of the estuary. The landings are those for Northumberland County. The third district is on the northern coast of Nova Scotia from Pictou on the west to St. Ann Bay in northern Cape Breton Island on the east. The landings are those for Pictou, Antigonish, Inverness, and Victoria counties. The principal river is the Margaree, which discharges into the Gulf of St. Lawrence Through a short estuary about midway along the coast of Inverness county, that is, the inner coast of Cape Breton Island. Tagging experiments have shown that the salmon of the Margaree coast, that is, within a few miles of the mouth of the estuary, tend to scatter more or less throughout the whole district, in which there are quite a large number of minor rivers or brooks that salmon ascend. The landings of salmon for these three districts from 1870 to 1950 inclusive are given in Tables II, III, and IV respectively.

The courses of the annual landings, as smoothed with 3-year moving averages, are placed one above the other in figure 2. It will be seen that they all resemble those for the Restigouche River and its associated district in showing a 9-10 year period in fluctuation, which is most pronounced in the 70s, 10s, 20s, and 30s. Whether or not this cycle is to be accepted, seeing that it is sometimes quite indistinct, there is clearly a complex general fluctuation in the salmon stocks of the region, with local variations.

Table II.
Hundredweights of salmon landed each year
in the Saint John system, New Brunswick.

	0	1	2	3	4	5	6	7	8	9
1870	5350	4855	5441	7080	6017	5822	2026	2286	2842	3563
1880	2259	721	2866	1216	2256	2594	1518	2579	2104	1888
1890	667	2291	2600	1833	2243	1625	2893	2986	2237	3422
1900	2912	2953	3358	3363	3803	4304	7158	4792	3690	2723
1910	3928	3873	3873	4895	4559	2863	4654	3115	2659	1321
1920	1798	4725	3149	3005	3246	3696	4352	3828	2806	3650
1930	6857	5819	3827	3549	4382	5138	5005	4753	3202	1679
1940	2238	4194	3043	3544	2512	1413	1546	1135	1600	2427
1950	1825									

Table III.
Hundredweights of salmon landed each year
in the Miramichi system, that is, in Northumberland county, N. B.

	0	1	2	3	4	5	6	7	8	9
1870	5227	4526	7005	12605	17073	8885	3385	7270	6840	4210
1880	2252	1997	3914	2312	3714	5114	3317	3578	3566	2736
1890	3793	4410	3576	7497	4619	3993	6876	3491	2905	3700
1900	3595	3982	3751	3571	3311	5111	6318	5268	4378	3985
1910	3259	2500	4324	5560	5802	8733	6269	4316	9236	3799
1920	3571	9654	6594	8915	12557	7964	5979	8297	4107	7549
1930	12037	8391	6031	8673	4594	3915	5146	5892	5637	4570
1940	5106	7224	3129	5158	3704	3254	4005	5021	4273	5189
1950	4102									

Table IV.
Hundredweights of salmon landed each year
in northern Nova Scotia, Pictou county to Victoria county inclusive.

	0	1	2	3	4	5	6	7	8	9
1870	5017	4669	5481	9030	10440	4381	3274	2703	2897	2271
1880	1496	1190	2045	2269	2413	3559	2942	3169	3397	3105
1890	2201	1660	2052	2460	2053	1465	1951	1475	2057	2391
1900	2133	2382	2002	1832	2071	2179	2717	2600	2481	1654
1910	2516	3112	3101	3863	5088	6048	2715	3520	2769	1745
1920	1250	2126	3174	4809	5050	3726	5963	6433	3439	4463
1930	7862	5505	4126	4838	3509	2882	3113	2227	2304	2477
1940	3195	3044	2468	2062	1935	1347	2276	1996	2627	2119
1950	2884									

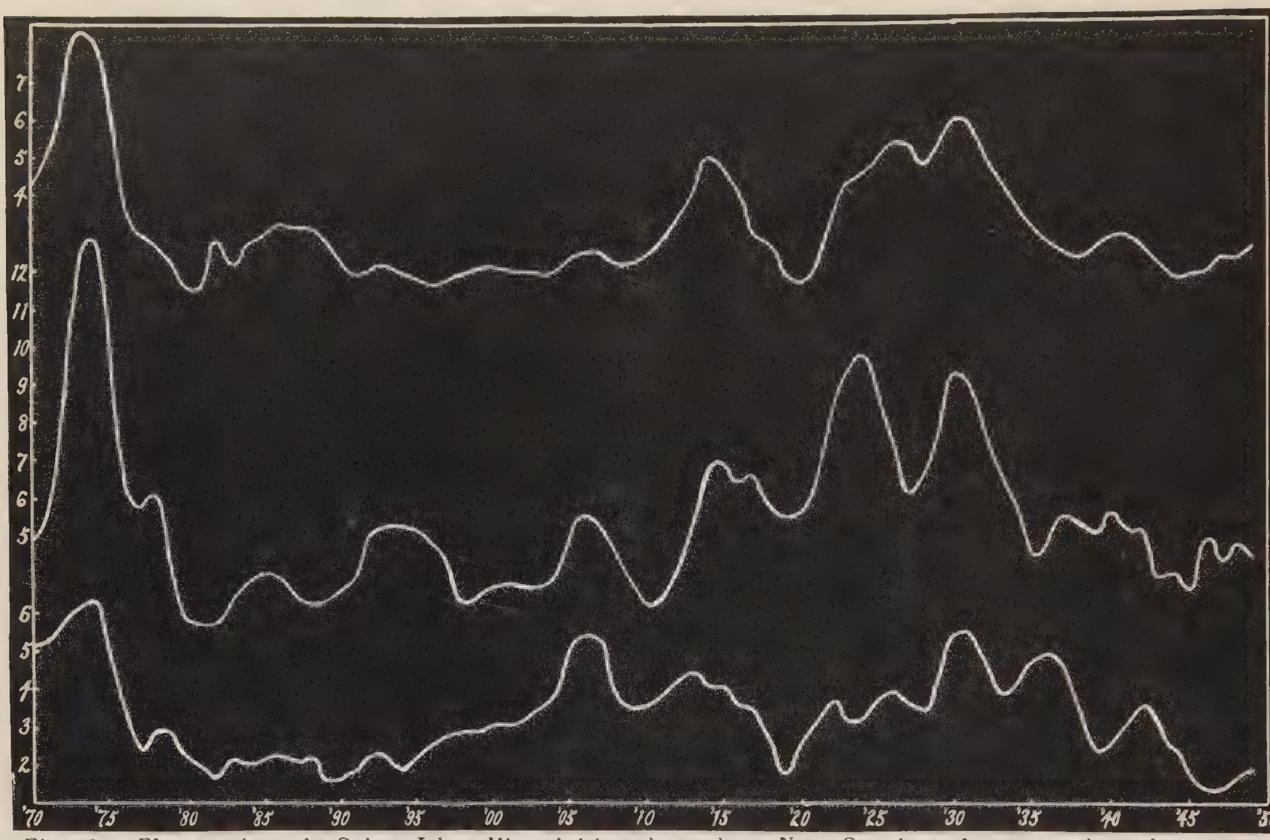


Fig. 2. Fluctuations in Saint John, Miramichi and northern Nova Scotia salmon, as shown by annual changes in catches in the Saint John district (Charlotte, Saint John, Kings, Queens, Sunbury, York, Carleton, and Victoria Counties, N.B.), the Miramichi district (Northumberland County, N.B.), and the northern Nova Scotia district (Pictou, Antigonish, Inverness, and Victoria Counties), all three curves Being smoothed by using a three-year moving average.

In some respects, a better picture is presented by the actual course of the landings from year to year, with the curves for the districts superimposed (fig. 3). There is a fair amount of agreement in the courses of the landings from year to year in the three districts. Of 80 changes from year to year, the direction of change agrees in all three districts in 35 cases, in only the 2nd and 3rd in 19 cases, in only the 1st and 2nd in 15 cases, and in only the 1st and 3rd in 11 cases. Proximity seems to operate in determining agreement. The peaks or years of abundance are far from being evenly spaced, even when there is agreement between districts. On the other hand, the greatest depressions or years of scarcity are fairly evenly spaced and agree pretty well between districts. They are the years 1871, 1881, 1890 or 1891, 1900, 1909, 1919 or 1920, 1928 or 1929, 1939 and 1947, but 1900 and 1947 are questionable.

Variation in Distinctness

The cycle was discovered only when it was quite distinct and repeated, which is perhaps a bare minimum for proper recognition. The two periods were in the Tens and Twenties. Older records showed much less pronounced fluctuations, except one in the Seventies, when statistics were being collected. Nor have there been such marked fluctuations since it was discovered, that is, in the Thirties and Forties. That a very distinct fluctuation has been repeated after a considerable interval was interpreted as representing a 48-year cycle. The indistinctness of the shorter cycle since gives support to that interpretation, but the details fail to show that the course of the fishery from the Seventies to the Twenties is being repeated. For the time being, chief reliance must be placed upon the fluctuations in the Seventies and Twenties. Uncertain as a cycle with long period may be, variation in distinctness of the cycle is definite and a feature that may help rather than hinder elucidation. The treatment of the Restigouche data by Phelps and Belding brought out the cycle more distinctly, but left the fluctuation in the Twenties as much the most striking of the five periods shown. That of the Seventies was even more outstanding from the accounts given of it.

Vagueness of the Period

Although Griswold refers to a nine-year cycle, his figures show periods of 8, 8 and 9 years (1929 p. 18). Phelps and Belding, using records

for 52 years from 1879 to 1930, deduced a 10-year cycle, and the main fluctuations shown in their graphs correspond roughly with the five decades covered. The numbers of years between successive troughs or crests are not, however, constant. The same applies to the commercial catches.

A rather reliable average length for the period can be obtained by averaging for the periods between the marked fluctuations of the Seventies and Twenties. For the commercial catches of various districts an average period of 9.6 years was calculated (Huntsman 1931). The figures of Phelps and Belding for rates of fishing in Restigouche angling give low figures in 1880-1 and in 1928-9 in agreement with the commercial catches, and accordingly yield the same average length for the period, 9.6 years. For the present that must be considered as the most probable length.

That this period is closely similar to that of the cycle in abundance of fur-bearing animals in the Canadian North West creates some confidence that it is a basic phenomenon. The period for the latter cycle was calculated (Huntsman 1931, 1937), as 9.6 years and Elton (1940) suggests the same. Both cycles agree in length and vagueness of the period, and also in variation in distinctness.

Location of Casual Factors

Griswold, following up an idea of Otto Pettersson of Sweden, related the cycle to a nine-year cycle of the tides, considering that the currents in the sea along the coast "move off and on shore in cycles of nine years" in conformity with the tide generating force. According to Doodson (1921 and private communication) the tidal cycles nearest in period have periods of 9.3 and 8.847 years in length. This would do well for a nine-year cycle, but not very well for a 10- or 9.6-year cycle.

Phelps and Belding (1931) made an excellent and thorough analysis of their facts in an attempt to elucidate a cause for the cyclical fluctuation in abundance. They concluded that it is something more potent than the numbers of breeding fish. The fish affected adversely or favourably to the same degree were not all of those taken in the river in the same year, nor those spawned in the same year, but those that migrated to the sea as smolts in the same year. This could be determined since the fish spawned in a given year remain for a variable number of years in the river and for a variable number of years in the sea before return. Also, the latter or sea age can be fairly well recognized by the size of the fish and the weights of the individual fish had been recorded.

They failed to get any correlation between the numbers of the breeding fish in the river during any one year and the numbers of their offspring. They did find a pronounced positive correlation between the 2-sea-year fish of one, the 3-sea-year fish of the next year, and the 4-sea-year fish of the following year. This means fish that descended the same year as smolts. They considered various possibilities that would fit this situation, and concluded that there must be "some favourable or unfavourable environmentak factor affecting the migrating smolt". They decided upon this as being "a sea condition affecting only the smolt of one year's migration", but considered also "a favourable or unfavourable river condition affecting only the smolt class as it prepares to leave the river".

Study of the catches of salmon in the sea with nets (Huntsman 1931) gave a similar result. It was obtained by comparing, not salmon of different sizes, that is, ages in the one river, but catches of salmon in districts that differ as to the size of the mature fish that are caught, that is, as to the sea age at which they are caught. The year of scarcity was seen as coming a year earlier at the head of the Bay of Fundy, where the salmon mature as grilse (1-sea-year fish) than in the Saint John fishery, where they mature mainly as average salmon around ten pounds in weight (2-sea-year fish), and also as coming a year earlier in the Saint John fishery than in the Gaspe region, where the mature fish are quite large (3-sea-year fish and older). This is illustrated (fig. 4) by the salmon scarcity of 1918 to 1921, which occurred in these three districts in 1918-1919, 1919- 1920, and 1920-1921 respectively. On the basis of sea ages of the prevailing fish, the three districts agree in haying salmon particularly scarce that were smolts in 1917 and 1918. It was considered that this pointed to "a factor operating near the time of descent of the salmon from the river as smolts" (Huntsman 1937). Such fish are exposed to the action of a common factor that may operate, not merely at the time of descent from the river, but also in the river during the year preceding descent or in the sea during the year following descent.

It might be argued that the fish from different districts are together in the sea for exposure to a common factor, but not in the separate rivers. Evidence is, however, against their being together in the sea. Also the factor may operate generally on the various rivers. Facts were seen to point to the factor being operative in the river (Huntsman 1931), since its action in causing scarcity of one-year class coincided with a particularly favourable effect on the abundance of the one or two following year-classes. Phelps and Belding were inclined to rule out the possibility of the factor acting in the river before descent of the fish as smolts by the argument that it would have to act not only on the parr about to descend, but also upon the younger parr present. However, the facts indicate that it does act on both, but in opposite ways, making the young parr abundant when it makes the old parr scarce. The favourable effect was seen, in comparing the conditions in different districts, as being "exerted during the first two years of fresh water life", and since the unfavourable effect operated near the time of descent of the older fish as smolts, it definitely placed "the

time of action of the unknown factor in the river period several years before its effect is apparent in the catches."

Reason for Opposite Actions of Factors

That the factor should at one and the same time make one year-class scarce and associated year-classes abundant finds explanation in the fact that in crowded quarters the fish interfere with each other. A factor that acts directly in making large parr scarce may act indirectly to make small parr abundant by thereby giving them less competition for food and more freedom from enemies if there is cannibalism.

That large parr keep down the numbers of small parr has been found in experiments from 1942 to 1945, in which under yearling salmon were planted in small, cold, spring-fed tributaries of the Pollett River of New Brunswick, which were without native salmon. There was good survival when no older parr were present, that is, the first time of planting, as shown by local seining the following summer. With equal numbers planted in 1942 and 1943, the yearling survivors as found in 1943 and 1944 for various brooks gave the following comparative percentages: Lee Brook, 6½ vs. 4.3; Gladstone Brook, 5 vs. 2; Parchard Brook, 8 vs. 1.3; Salmon Hole Creek, 4½ vs. 0.1. There were thus markedly fewer survivors from the second planting. A third planting of from three to six times as many underyearlings was made in the brooks in 1944. In the colder parts, some of the parr at least remain for a third year before descending as smolts, so that the underyearlings

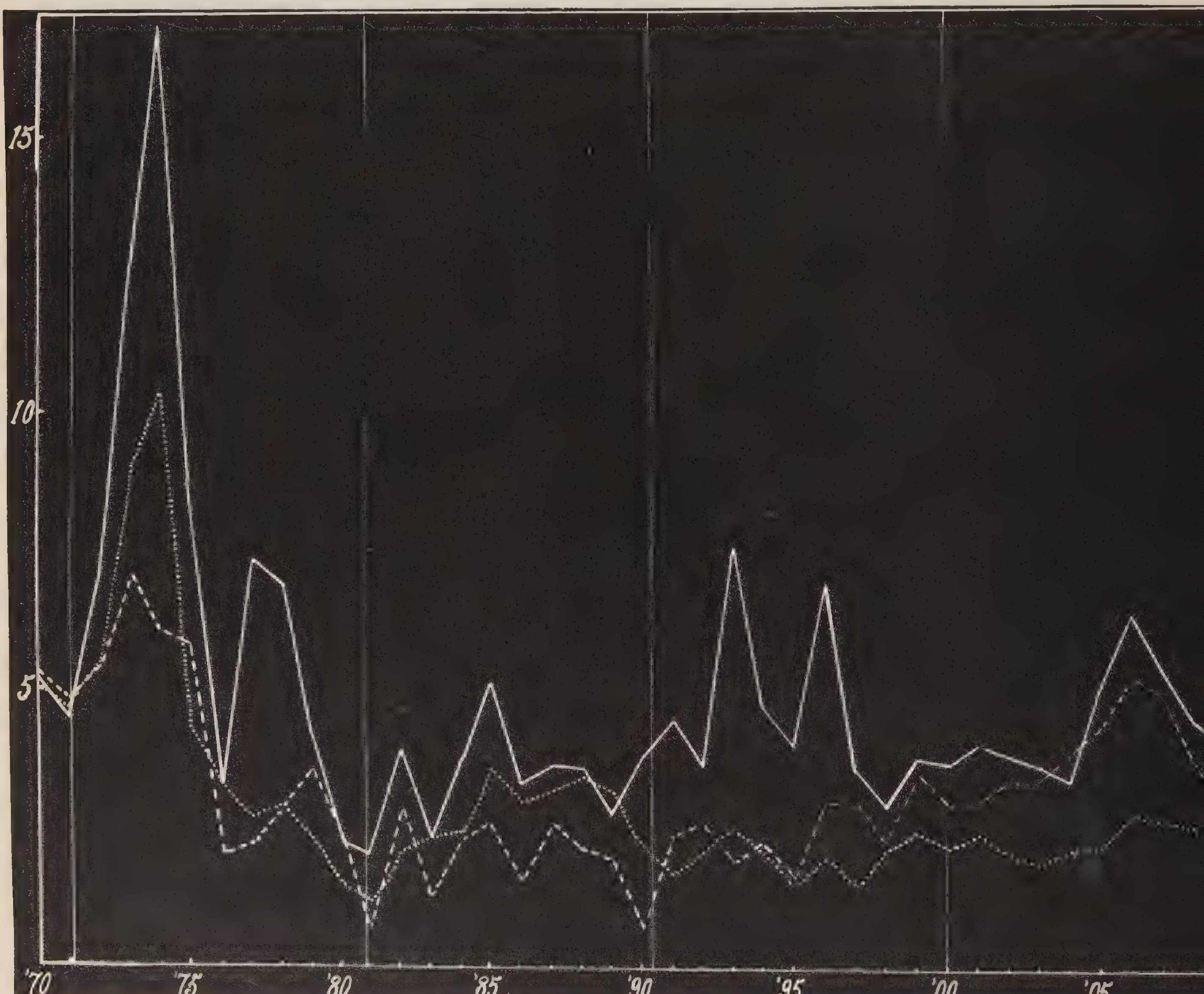
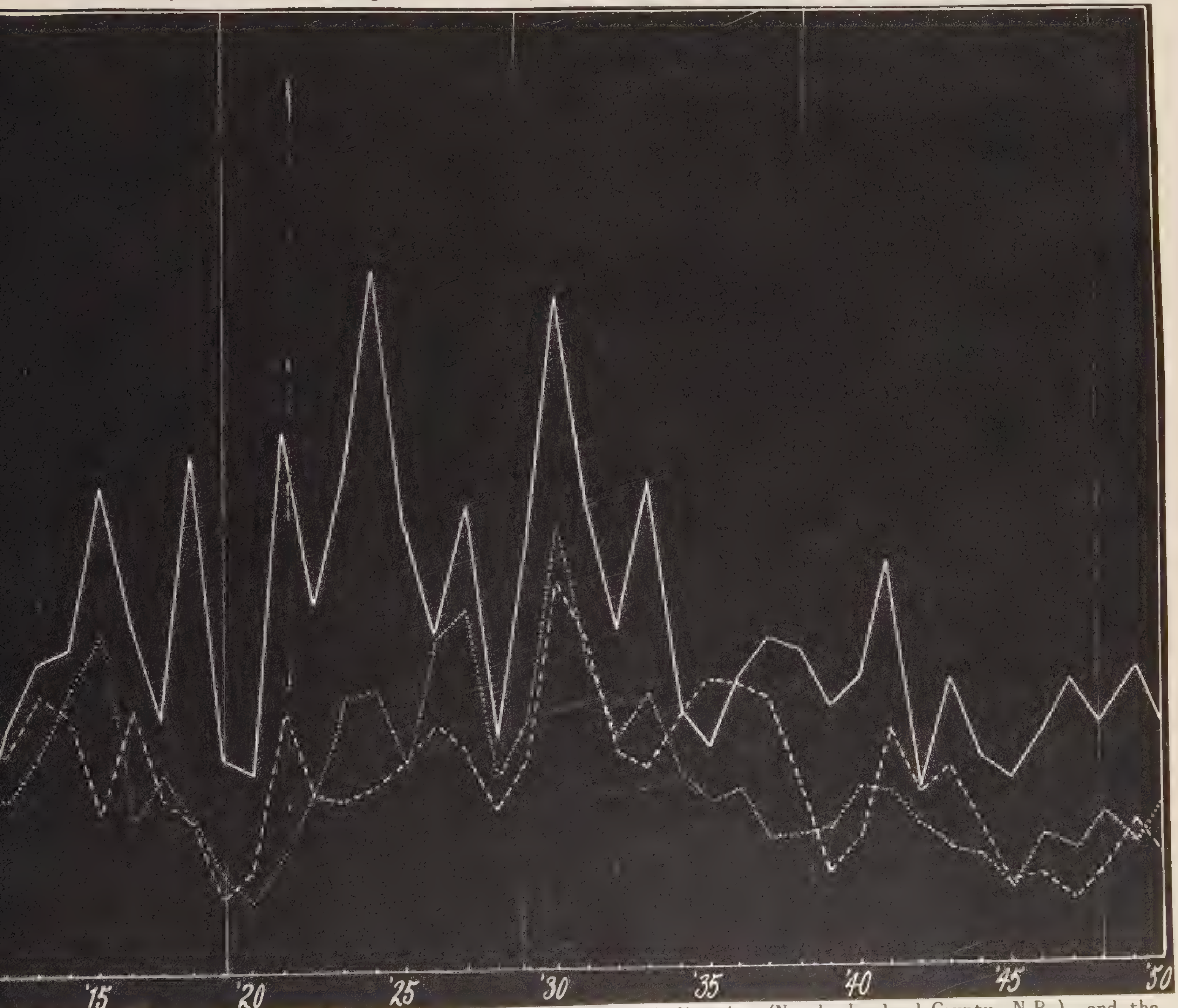


Fig. 3. Fluctuations in Saint John, Miramichi and northern Nova Scotia salmon, as shown by annual changes in catches in the Saint John district (Charlotte, Saint John, Kings, Queens, Sunbury, York,

there were with not only parr a year older, but also parr two years older until the latter descended in the spring (June) after they had begun to feed actively. In 1945, seining showed an even smaller survival as yearlings of the much larger numbers planted in 1944 than of those planted in 1943. The relation of older parr to survival of the young was well shown by the changing picture going upstream from the mouth in Parchard Brook, the water in summer becoming progressively colder and with less food on going upstream. The percentages and average sizes of parr of different sizes in four successive sections of the brook were as given in Table V. It is striking that no yearling survivors were found in the uppermost section where some of those first planted had not yet descended, but were remaining for a fourth year of growth, and were no larger than the yearlings in the lowermost section. The results elsewhere with less pronounced gradation varied from stream to stream in accordance with differences in conditions. Lee Brook, which had the highest survival (4.3%) of yearlings in 1944 from the second planting, showed in 1945 the lowest concentration as well as the lowest proportion of yearlings (22%) to older parr in spite of the 1944 planting being over five times as great as the 1943 planting. This indicates that high survival of one year-class keeps down the numbers of the following year class. In contrast, Salmon Hole Creek, which had the lowest survival (0.1%) of yearlings in 1944 from the second planting, showed in 1945 from a planting scarcely three times as great as previously the highest proportion of yearlings



carleton, and Victoria Counties, N.B.), the Miramichi district (Northumberland County, N.B.), and the northern Nova Scotia district (Pictou, Antigonish, Inverness, and Victoria Counties.

(73%). This creek has the coldest water, and in it the parr show the slowest growth. The picture found in this stream indicates that the first fish planted (1942) grew so slowly as to occupy during the next year the habitats suitable for

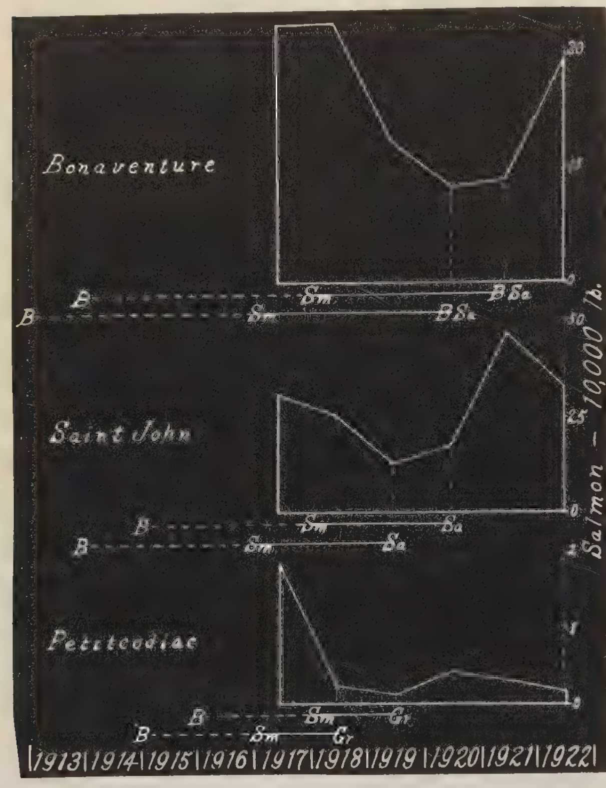


Fig. 4. Salmon scarcity of 1918 to 1921, as shown by Petitcodiac River system below, Saint John River system in the middle and Bonaventure County, Que. above, in relation to main life history of the local salmon

Table V.
Percentages and average lengths of salmon parr at various ages found in successive sections of Barchard Brook, N. B., from the mouth upstream, in the summer of 1945, after plantings of under-yearlings in the three previous years.

Section	a	b	c	d
1-yr. olds				
percentage	100	87	60	0
av. length (cm.)	12.1	11.4	10.9	
2-yr. olds				
percentage	0	13	40	83
av. length (cm.)		13.1	12.4	12
3-yr. olds				
percentage	0	0	0	17
av. length (cm.)				12

such small fish and virtually eliminated those newly planted. The latter, without good habitats, doubtless became prey to the brook trout (**Salvelinus fontinalis**) in which the stream abounds. With the fish from the second planting thus eliminated, there was habitat room for a relatively high survival from the third planting.

Why Scarcity is Pronounced

Griswold recognized a periodicity in the years that were bad for angling, that is, in years of scarcity of fish. Phelps and Belding remark that in emphasizing the bad years he acted "like a true fisherman". But the 9-10 year periodicity does appear to be more distinct for bad years than for good years. The reason for this seems apparent. The factor which is responsible for the periodicity acts definitely over the whole river system when of a character to bring about scarcity. There seems to be no evidence that it acts so definitely when of a character to bring about abundance directly. In other words, the numbers of salmon are more easily reduced to very low levels than increased to very high levels. Moreover, interference between salmon parr of different ages when together in the close quarters of a stream tends to make marked fluctuations in the numbers that survive in successive year classes. When the factor makes old parr scarce, it indirectly makes the young parr abundant. Unless the factor again acts to reduce the numbers of the latter when they become old parr, a scarcity of adults in one year will be pronounced by being followed the next year by a comparative abundance of adults. Similarly, if the factor acts to reduce the numbers of old parr by a year-class already low in numbers through action on them when young of a preceding abundant year-class, the drop to scarcity will be very steep.

Nature of Some Causal Factors

Study of the factors affecting the numbers of the young salmon about the time of their descent to the sea, that is during the last year of parr life, failed to show disease as acting, nor was food seen to be of particular importance except as determining the rate of growth. The factor that emerged was predation by mergansers and kingfishers, which take very large parr in their last year of river life (White 1936, 1937). This fits the requirement for a factor that produces pronounced scarcity of salmon through cutting down their numbers in their last year of river life as parr. While this would seem to shift the problem to that of the varying abundance of fish-eating birds, it developed that the availability of the fish to the birds might be the factor. Kingfishers in rearing their young along the Margaree River depend for food upon young salmon and trout, and get them in the vicinity of their nests. Study of their food from May to September of 1937 showed that the percentage of trout in their food from month to month followed very closely the mean monthly discharge of the river,

that is, the water height (White 1937). There was a rapid fall from May to July and an abrupt rise from August to September in both. When the river water was high the kingfishers fed in small spring-fed brooks and pools where small trout were abundant, but when the river water was low they took from the river the young salmon, which constitute their main food in this region. The percentages of salmon parr in their food, therefore, varied inversely as the water height, as shown in figure 5. Low and clear water in the river would thus favour heavy predation on young salmon by fish eating birds, by making the fish more readily available. Doubtless this applies not only to the kingfisher, but also to the merganser, which is known to take parr from open rapids in the dead of winter, but whose chief feeding time is during the summer.

Figures proved to be available for testing a possible simple relationship between river height and salmon abundance. Summer discharge of the Northeast Margaree River, N. S. from 1922 to 1932 showed (fig. 6) quite a good correlation with the commercial catch for the Margaree region three years later, that is, from 1925 to 1935 (Huntsman 1937). This agrees with the fact that the salmon catch in any one year consists mainly of fish

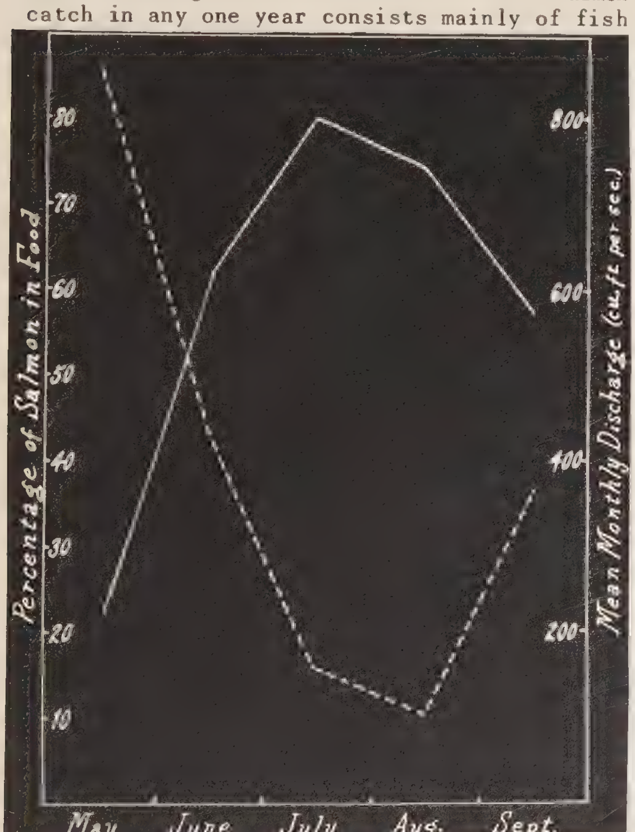


Fig. 5. Percentage of salmon in kingfishers' food, as found by Mr. H. C. White on the Northeast Margaree River in 1937 for each month from May to September in comparison with the mean monthly discharge as recorded by the Dominion Water and Power Bureau.

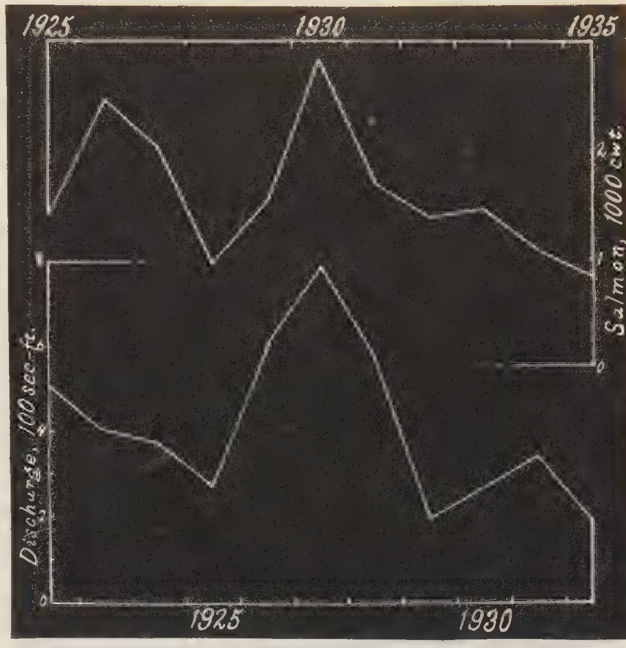


Fig. 6. Yearly salmon catch for the Margaree region (north Inverness County, N.S.) from 1925 to 1935, in comparison with the mean discharge for June to August of the Northeast Margaree River three years earlier, from 1922 to 1932.

that were smolts two years previously, that is, were in their last year as parr in the river three years previously. There was also an indication of scarcity of salmon in New Brunswick waters in 1928 as compared with neighbouring years related to low rainfall in 1925, but rainfall is not a very good index of water heights in the rivers. The inadequacy of existing records both of rainfall and of river discharge has prevented proper development of the matter.

However, an occasion offered (Huntsman 1941) to test the relation of a predation by birds on young salmon in the year before their descent as smolts as the factor through which summer water levels in the Margaree River bring about fluctuations in salmon abundance. The birds were controlled in 1937, a year with a very dry summer. The records showed (fig. 7) that the net catches of salmon on the neighbouring coasts from 1934 to 1939 had been fluctuating in correspondence with summer water levels three years previously, that is, from 1931 to 1936. Then with low water in 1937, but with bird control, the catch in 1940 went sharply up instead of further down.

It should not be thought that action of the water height in affecting the numbers of young salmon in streams is wholly dependent upon the activities of fish-eating birds, which are not always present. Low water in summer may reduce numbers of young salmon in other ways than through predations by birds. In general it is obvious that to have fish you must have water, and to some extent the less water there is the fewer fish there are. But also low water, which means

lessened stream flow and usually more sunshine, raises the water temperature in summer. In the southern part of the salmon's range, as in Nova Scotia and New Brunswick, the rise under certain meteorological conditions will be sufficient to kill the young salmon in some streams (Huntsman 1946). Even when the temperature is short of being lethal, it will make the salmon sluggish in comparison with species that are active through a higher range in temperature. Eels have such a higher temperature relation and they prey upon

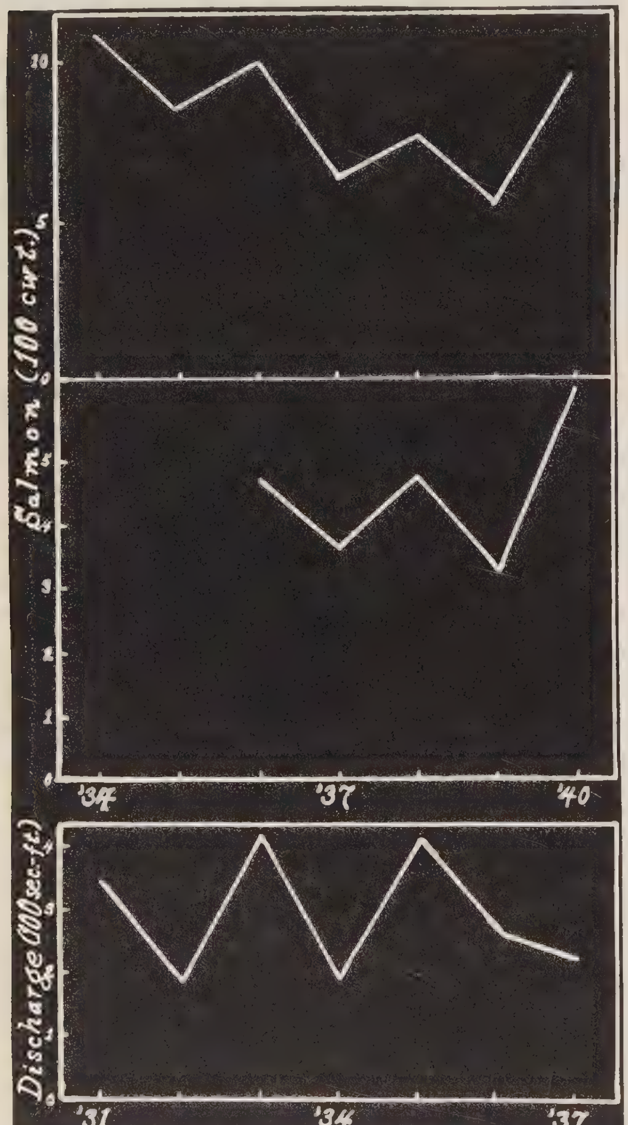


Fig. 7. Yearly salmon catch for the Margaree region (north Inverness County) in upper graph and for the restricted Margaree district (Whale Head to Cheticamp Point) in middle graph from 1934 to 1936 respectively to 1940, in comparison with the mean summer (June to August) discharge of the northeast Margaree River three years earlier, from 1931 to 1937.

young salmon in warm streams. Experiment has just shown that the summer season for a stream then suitably warm for eels but too warm for salmon increases the young salmon mortality greatly. When 4,200 marked yearling salmon were planted in the Rawdon River, Nova Scotia in June of 1945, the trap operated the next spring to take the descending smolts took only four of these, that is, 0.01%. In contrast to this, from a lot of 200 yearlings planted in the river in November of 1949, after the eels had ceased to be active, 83, that is 41%, were taken when descending the next spring.

Low water at other seasons than summer may affect salmon abundance. Hagman (1938) adduces evidence that low water in winter in Swedish and Finnish waters adversely affects the numbers of salmon from eggs developing in the spawning beds during the winter. This is apt to occur only in northern waters where winters are very severe. Also, spawning may be prevented by low water in the streams at spawning time. Mr. H. C. White trapped Holmes Brook, a tributary of the Petitcodiac River, to take the salmon ascending in the fall to spawn. In 1944, 137 fish ascended, in 1945 there were 92, and in 1946 only one. The fall of 1946 was very dry, so that, as reported by Mr. White, the flow of the brook was reduced to a mere trickle.

That river height depends upon run-off from rainfall and melting of snow and ice is well appreciated. To solve what is seemingly the main part of the problem in salmon abundance, there will need to be thorough study of all these factors in relation to specific changes in the particular stock of salmon in question.

That the causal factor for the 9.6-year salmon cycle should be narrowed down to rainfall suggests that it is dependent upon a climatic oscillation.

Maritime Salmon and Fur Bearers of the Northwest

That salmon in the Maritime Provinces and fur-bearing mammals in the Northwest should both have a 9.6-year cycle in abundance evokes the question as to what might be a common factor for animals living so differently and so far apart. If the salmon cycle is determined by a tidal cycle as was first suggested, no connection with land animals of the interior of the continent seems conceivable. But if rainfall is the causal factor, and, if this varies with some climatic oscillation, a connection seems obvious. Elton (1937) has predicted a climatic oscillation as being responsible for the cycle in the Northwest. How this would operate on the animals there is not evident. However, the region in which the "rabbit cycle" is most distinct is decidedly deficient in rainfall and water is essential for life. Water might well be the limiting factor for the snowshoe rabbit in a relatively arid region. How dependent the rabbit may be upon precipitation of water does not seem to have been studied.

Summary

Records for eighty years reveal fluctuations in salmon abundance in eastern Canada, in which can be recognized a cycle with a period of nine or ten years, of which the average length has been 9.6 years.

The records are of fishermen's catches. Although there are many variables to prevent these catches properly representing the abundance of the fish, the fact that the cycle appears both in rod catches in the Restigouche River and in net catches in the adjacent sea, as well as in net catches for district after district along the coast, engenders confidence that there is definitely such a cyclical change in abundance of salmon and that it is widespread.

Years of scarcity show the periodicity more clearly than do years of abundance. The extent of the fluctuations and the distinctness of the periodicity have varied greatly and together. The cycle is a rather vague one.

The timing of the cycle for salmon of different sizes, that is, of different ages for sea life, whether they are in the one river or in different rivers, shows that the causal factors for the cycle act on the salmon near the time of their descent from the river as smolts. That the factors, when causing scarcity of a year-class, act favourably on the numbers of the next one or two year-classes, indicates that they act on the fish when they are together in the river. The factors seem to act most definitely and generally in causing scarcity of salmon and this makes the years of scarcity more distinct. Also, their opposite action on successive year-classes emphasizes the distinctness of the years of scarcity.

Predation by fish-eating birds was found to be a cause of death of salmon parr in the Northeast Margaree River. As the birds take the large parr, such predation fits the requirement for a factor acting directly only on the parr about to become smolts. Predation by the birds on the salmon parr is made much easier by lowness and clearness of the water. Varying height of the river water, as determined by rainfall, is thus seen as the basic variable to determine periodic scarcity in salmon. A correlation was found between height of the river water during the summer months and the abundance of the salmon then in their last year in the river, as shown when they were taken in the sea with nets three years later as mature fish. Control of the birds with the water low resulted in the net catches three years later being high and not low, thus breaking the correlation.

That the basic variable for the 9-10 year cycle for salmon in eastern Canada is river height from rainfall points to a climatic oscillation with such a period. This oscillation may well be responsible for the cycle in abundance of furbearing animals in the Canadian Northwest, which show a cycle of the same length.

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A NEW FORM OF PERIODOGRAM

by

Edward R. Dewey

As student of cycles know, a periodogram is merely a "gram" or recording of the cycles or periods present on the average in a series of figures.

Cycle length in time is represented along the horizontal or X axis, and the strength or amplitude of each of the periods investigated is shown on the vertical or Y axis. The points thus determined are connected by straight lines.

The Traditional Form of Periodogram

For example I reproduce below in Fig. 1 a periodogram of motion picture stock prices prepared by E. S. C. Coppock of San Antonio, Texas. This is one of six periodograms of stock prices by Mr. Coppock which we published for you in our March 1951 report. It is in the usual conventional form.

The numbers from 10 to 70 along the bottom refer to months. The scale represents a measure of the relative strength of the average cycle found for the number of months indicated. Thus the first peak with a value of 30 at 18 months indicates that if you take the entire series of 221 monthly values, arrange them in twelve rows of 18 items each, add each column to obtain 18 sums, and subtract the smallest sum from the largest sum you will get a value of 30.

Similarly if you arrange the data in eleven rows of 19 items each, add each column to obtain 19 sums, and subtract the smallest sum from the largest sum, you will get a value of 15, as you can read from the chart.

This proceedure is one step in harmonic analysis as described by Professor H. T. Davis of Northwestern University in his book **The Analysis of Economic Time Series.**

The fact that the arrangement in 18 columns produces larger differences than the arrangement in 19 columns indicates **in a very crude sort of way** that there is more of a chance of a cycle of 18 months in length than of a cycle 19 months in length.

The method is wholly inadequate as explained in the Technical Section of the March report on page 94, but that is

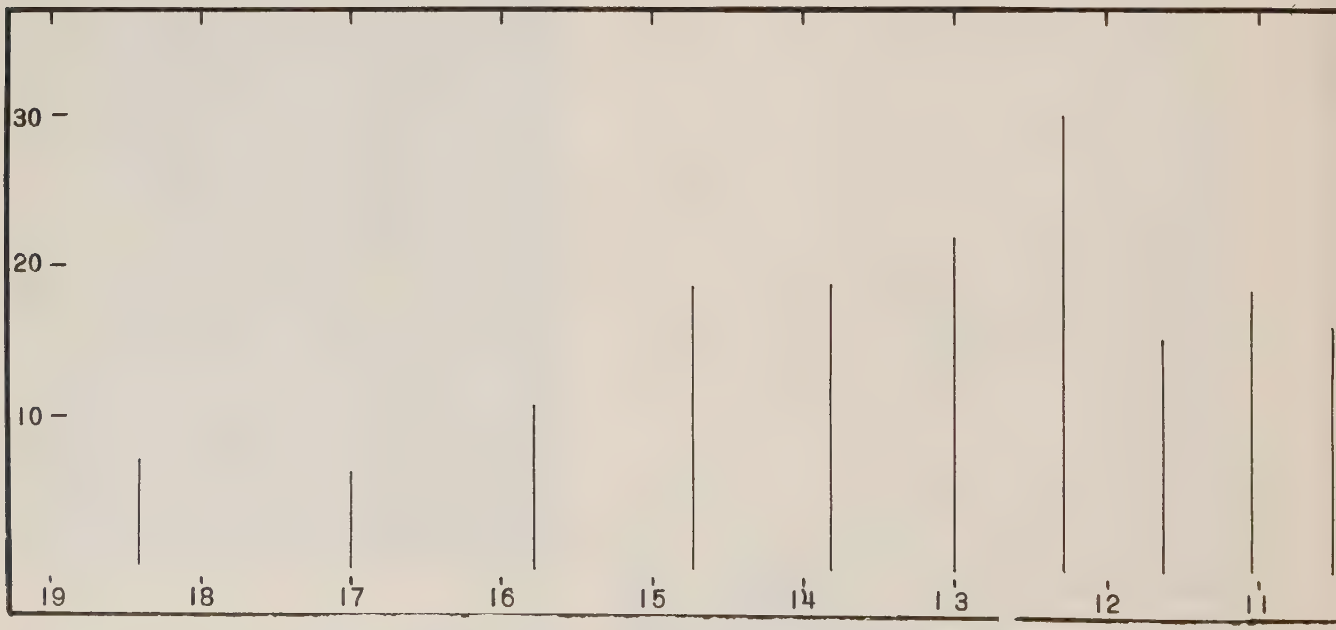


Fig. 2. The new form of periodogram. This chart plots the same values shown in Fig. 1 but uses a harmonic horizontal scale and represents the harmonic values by vertical bars. A harmonic horizontal scale is one where unit fractions of the length of the series of figures being analized

another story. This paper is concerned merely with the form of the periodogram, not with the significance of the Y values in the particular method used.

The New Form of Periodogram

Consider now a new form of periodogram. The vertical or Y scale remains the same, but the horizontal or X scale represents **harmonics** of the total length of the time series, in this instance 221 months. It is numbered from right to left so that the resulting periodogram will be as nearly as possible in the conventional form.

The second change introduced by the new form has to do with the representation of the values for each length of cycle investigated. Instead of representing these values by points connected by lines, they are represented by vertical lines, and in most instances the tops of these lines are unconnected.

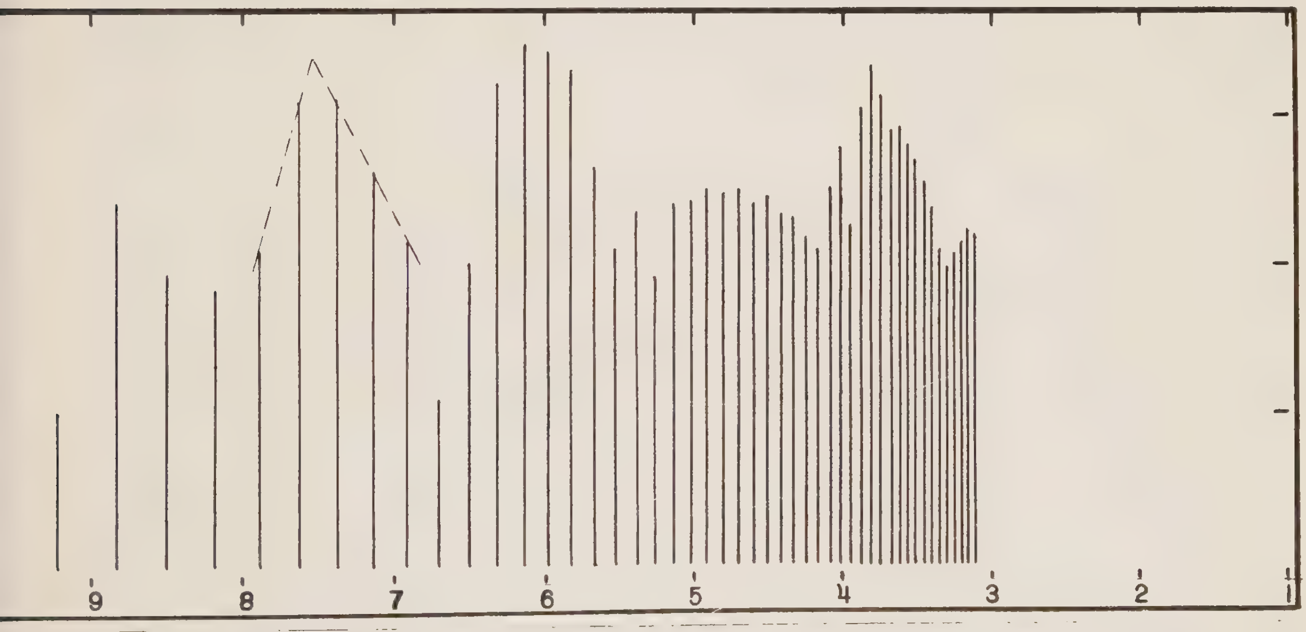
The periodograms of motion picture stock prices shown in Fig. 1 is replotted for you on the new form in Fig. 2 below.

The figure 1 at the right of the horizontal scale represents the fundamental—in this case 221 months. The figure 2, to its left, represents the second harmonic (1/2 of 221 months) or 110.5 months. If Mr. Coppock had investigated a cycle of this length it is at this point that he would have plotted the amplitude or strength of his result, if he had used the new form. If he had investigated a cycle of 73.7 months he would have plotted his Y (vertical) value at 3, because the third harmonic of 221 is 73.7 (221 ÷ 3 = 73.7), and so on.

The values of the first twenty harmonics of 221 months are given below in a table reproduced from the March 1951 report.

Harmonics of 221 Months.

Harmonic	Length in months	Harmonic	Length in months	Harmonic	Length in months
Fund.	221	8th	27.6	15th	14.7
2nd	110.5	9th	24.6	16th	13.8
3rd	73.7	10th	22.1	17th	13.0
4th	55.3	11th	20.1	18th	12.3
5th	44.2	12th	18.4	19th	11.6
6th	36.8	13th	17.0	20th	11.1
7th	31.5	14th	15.7		



re equidistant. Thus, in this case, the position marked 1 represents a cycle of 221 month, the osition marked 2 represents a cycle of ½ of 221 month (110½-month), the position marked 3 repreents 1/3 of 221 month (71 4/7 month), etc.

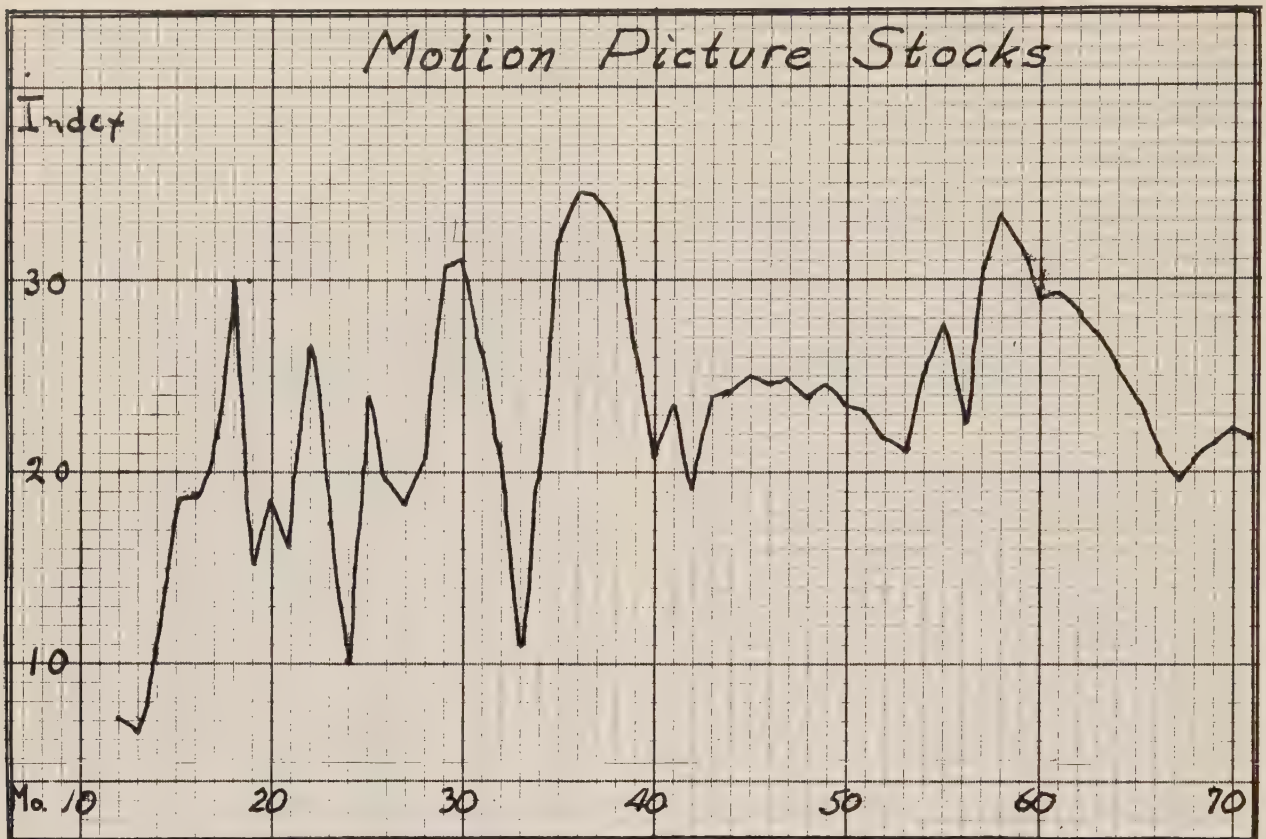


Fig. 1. Periodogram of motion picture stock prices, January 1932 - May 1950, as prepared by E. S. C. Coppock. It is in the usually accepted form, — that is, a horizontal scale representing wave length in months (or some other time unit), with the periodogram values expressed by points connected by lines.

Using the New Form

But Mr. Coppock did not investigate harmonic values. He investigated values for integral months, i.e., 71 months, 70 months, 69 months, 68 months, etc. Before these values can be plotted on the new form of periodogram they have to be converted into harmonic values, as our horizontal scale now represents harmonics instead of months. To get these harmonic values we divide 221 in turn by each of the monthly values that Mr. Coppock did investigate, with the results shown in the table below (page 57).

We now plot these values as straight vertical lines on the form of periodic table suggested above.

The original periodogram gives you the impression, from the fact of peaks in the curve, that there is a liklihood of cycles at 18 months, 22 months, 25 months, between 29 and 30 months, at 36 months, and at 58 months.

The new form tells you at a glance that you need many more periodic tables of shorter length so as to get at least three or four values between each harmonic, and that for the longer cycles the computation of periodic tables for each month represents a tremendous amount of waste effort.

The spacing between the 7th and 8th harmonic intervals is about right. All four of the values given are doubtless due to an average cycle at about 29 1/2 months, which has more and more effect on the periodogram as the periodic tables get closer and closer to its true length.

But look at the waste of effort required to indicate the average cycle at 58 months. Four periodic tables between 57 and 67 months would have been adequate.

And at the other end of the spectrum consider the amplitude at 12 and 13 months with more than an entire harmonic interval between them. These amplitudes could both easily be the result of a 12 1/2 month cycle between harmonics 17 and 18. This cycle could be as big as the 18-month cycle.

Speaking of this 18-month cycle, we need about two more values between 17 and 18 months and two more between 18 and 19 months before we can have any adequate idea of its true length.

Using the new form you can of course connect the tops of the bars where there are several bars to a harmonic interval as I have done between the 7th and 8th harmonics, but to connect the tops of bars separated by half a harmonic interval or more is not only useless but may be highly misleading.

Lengths in Months and Corresponding Harmonic Values

A	B	A	B	A	B	A	B
Lengths Investi-gated in Months	Harmonic Values (221 ÷ A)	Lengths Investi-gated in Months	Harmonic Values (221 ÷ A)	Lengths Investi-gated in Months	Harmonic Values (221 ÷ A)	Lengths Investi-gated in Months	Harmonic Values (221 ÷ A)
71	3.11	56	3.95	41	5.39	26	8.50
70	3.16	55	4.02	40	5.53	25	8.84
69	3.20	54	4.09	39	5.67	24	9.21
68	3.25	53	4.17	38	5.82	23	9.61
67	3.30	52	4.25	37	5.97	22	10.05
66	3.35	51	4.33	36	6.14	21	10.52
65	3.40	50	4.42	35	6.31	20	11.05
64	3.45	49	4.51	34	6.50	19	11.63
63	3.51	48	4.60	33	6.70	18	12.28
62	3.56	47	4.70	32	6.91	17	13.00
61	3.62	46	4.80	31	7.13	16	13.81
60	3.68	45	4.91	30	7.37	15	14.73
59	3.75	44	5.02	29	7.62	14	15.79
58	3.81	43	5.14	28.	7.89	13	17.00
57	3.88	42	5.26	27	8.19	12	18.42

RESUMÉ OF CYCLES–A MONTHLY REPORT

October 1951

The **Director's Letter** tells five things we do not know about cycles and six things we do know about them. It tells how to apply such knowledge as we do have.

The **Research** department contains four articles viz: (1) The 37-Year Cycle (2) The 37-Year Cycle in the Variation in the Length of Time between Sunspot Maxima, (3) Stock Market Cycles by "Predix," and (4) Marechal's Stock Market Forecast of 1933.

The **first** article tells that a cycle of about 37-years in length has been observed by various workers in 12 different phenomena, namely in the variation in the length of time between sunspot maxima (since 301 A.D.), in sunspots with alternate cycles reversed (since 1749), in the frequency of aurora borealis (since 385 A. D.), in the frequency of Chinese earthquakes (since 200 A. D.), in the flood tides of the river Nile (since 622 A. D.), in the frequency of severe winters in Europe (since 330 A. D.), in temperature at New Haven (since 1781), in the growth of Arizona pines (since 1460), in the abundance of lynx (since 1735), in wheat prices (since 1265), in cotton prices (since 1731-32), in common stock prices, (a) in railroad stock prices (since 1831), (b) in industrial stock prices (since 1871).

It proposes in a series of 12 articles to examine the alleged existence of this cycle.

The **second** article discusses a cycle in fragmentary sunspot data from 300 A. D. to the present time, alleged by H. W. Clough, which averages 37 1/2 years in length, but which varies in length.

The **third** article describes a "comprehensive, scholarly, cycle analysis" of stock market prices 1854-1951, and a projection of the indicated cycles to 1972, as published by Vedder Hughey under the pseudonym of "Predix".

The **fourth** article shows a stock market forecast made in 1933 by George Marechal which "took into account all important cycles". The article compares this forecast with actual behavior for the 16 years since it was made.

The report also contains five pages of letters, two pages of questions and answers, and one page of additions to the library, with comments in regard to each.

With the report there is also a 28-page supplement, **Cycle Analysis: The Moving Average** by Edward R. Dewey, (Technical Bulletin No. 4 of the Foundation for the Study of Cycles).

This bulletin is one of "a series of simple informal Technical Bulletins on the subject of cycle analysis . . . . intended primarily for natural scientists such as biologists, geologists, physicians, dendrochronologists, climatologists, astrophysicists, agronomists, hydrologists; for social scientists such as sociologists, economists, anthropologists; for business statisticians not previously too familiar with analyses of this sort, and for classroom use in courses of statistics."

The table of contents of this bulletin is as follows:

November 1951

The **Director's Letter** tells the need of understanding cycles if we are to control wars and depressions, and offers a conjecture as to why human beings respond to cyclic forces.

The **Research** department contains four articles, as follows:

(1) The 41-Month Cycle in Industrial Common Stock Prices, (2) The Need to Know the Cause of the 10-Year Grasshopper Cycle, (3) The 700-Year Cycle in Japanese Climate, and (4) The 37-Year Cycle in Sunspots with Alternate Cycles Reversed.

The **first** article shows that a cycle of about 41 months in length has been present in industrial common stock prices from their beginning in 1871 to date. Discovered in 1912 it has continued for 39 years since discovery. Its average length for the past 80 years has been about 40.7 months or 3.39 years. The important task ahead is to know when it will be strong, when weak; when it will come early, when late. The article is illustrated with five charts.

The **second** article is largely an amplification of remarks of Professor J. H. Pepper and J. P. Corkins of the Montana Experiment Station as printed in the Country Gentleman for June 1951.

The **third** article translates the table of contents and reproduces seven charts from a book written in Japanese by Professor Hideo Nishioka of Keio University in Tokyo entitled **History of Cold and Warmth—The Theory of a 700-Year Cycle in Japanese Weather**. Professor Nishioka's belief in the existence of a 700-year cycle in temperature in Japan is based upon tree rings, historical chronicles, the distribution of various plants over previous centuries, and archaeological discoveries in regard to the abundance of various kinds of shellfish which lived in Japanese waters during the various past ages.

The **fourth** article reports upon the work of G. T. Lane in connection with sunspots with alternate cycles reversed. A cycle or cycles of this general order of magnitude would seem clearly to be present but the article states that so far it has not been possible to determine the exact length of this cycle with assurance.

The issue concludes with a list of new members of the Foundation for the third quarter of 1951, five pages of letters, additions to the library, and a questionnaire.

December 1951

The **Director's Letter** reviews the accomplishments of the Foundation for 1951. It restates the objectives of the Foundation, and names the seven things accomplished during the year toward the furtherance of these objectives. It tells something of the plans for 1952.

The **Research** department contains three stories viz: (1) Cycles in the Prices of Malleable Iron Pipe Fittings, (2) The 37-Year Cycle in the Frequency of Aurora Borealis, (3) The 41-Month Cycle in the Prices of Common Stocks.

The **first** article tells of four cycles found in the prices of Malleable Iron Pipe Fittings and shows how they continued for 2 1/2 years after constructive discovery and for 5 1/2 years during the period under study for which data were originally missing.

The **second** article, in regard to the 37-year cycle in the aurora, shows that from 385 A. D. to 1625 the length of this cycle seems to be approximately 35.9 years in length. The article calls attention to the fact that if the length of this cycle in these figures really is 35.9 years and if the length in other phenomena really is 37 years there is no possibility of any interrelationship.

The article also calls attention to the fact that the indicated length of 35.9 years is very close to the synodic period of Saturn and Neptune, but suggests that much more work needs to be done in respect to this cycle before we would be in a position to conjecture interrelationship.

The **third** article shows a manipulation of common stock prices by G. T. Lane from 1835 to date which indicates the possibility that the 41-month cycle, first discovered in 1912, may be a compound cycle made up of cycles slightly longer and slightly shorter than 41 months. The future behavior of this cycle in these figures, if this is the true explanation, is discussed.

The **Foundation Affairs** department tells of a gold medal presented to John Nelson, Propagation Analyst of the R. C. A. Communications, Inc. for "notable service in the field of radio propagation and planetary cycles".

The issue concludes with a 10-page index of Volume II.

CYCLE DATA

The following has been received from the Hudson's Bay Co.:
Hayes River ice break up, York Factory, Manitoba

1900	Apr. 28.	2nd move on May 16.
1901	May. 3.	" " " May 9.
1902	May 8.	
1903	No Record	
1904	May. 12.	" " " May 22.
1905	May. 30.	" " " June 2.
1906	May. 27.	" " " May 30.
1907	June 3.	
1908	No Record	
1909	May. 24.	
1910	May. 13.	
1911	May. 11.	
1912	No Record	
1913	June 2.	
1914	May. 24.	
1915	May. 13.	
1916	May. 23.	
1917	May. 30.	
1918	May. 31.	
1919	May. 19.	
1920	No Record	
1921	May. 12.	2nd move on May 21.
1922	May. 17.	
1923	May. 6.	2nd move on May 26.
1924	May. 16.	
1925	May. 25.	
1926	May 11.	
1927	May 20.	
1928	May 14.	
1929	June 1.	
1930	No Record	
1931	May 22.	
1932	May 11.	
1933	May 22.	
1934	May 29.	
1935	May 19.	
1936	May 22.	
1937	May 3.	
1938	May 10.	2nd move on May 13.
1939	May 14.	
1940	May 20.	
1941	May 12.	
1942	Apr.27.	
1943	May 20.	
1944	May 13.	
1945	May 26.	
1946	May 24.	
1947	June 3.	
1948	May 21.	
1949	May 21.	
1950	May 23.	2nd move on May 25.
1951	May 5.	" " " May 11.

NOTES AND NEWS

Page 20 of the autumn issue of the Journal of Cycle Research omitted mention of the fact that the material reported upon had been gathered during the study financed by the Arctic Institute of North America.

A section that places on record cycle data that may be useful raw material for cycle students appears in this issue. Contributions of cycle material are invited for future issues.